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THE CLIMATOLOGY OF THE VINE (*VITIS VINIFERA* (L.) [2] A COMPARISON OF TEMPERATURE REGIMES IN THE AUSTRALIAN AND MEDITERRANEAN REGIONS

BY J. A. PRESCOTT[1]

Summary

The distribution and areas of Australian viticultural locations have been illustrated on two maps and are shown to fall within the limits of 57°F (13•9°C) and 65°F (18•3°C) mean annual temperature and 8°F (4•4°C) and 15°F (8•3°C) temperature amplitude.
These temperature limits have been projected on a map of the Mediterranean region and the areas corresponding to Australian conditions indicated. These are in general concentrated round the western basin of the Mediterranean Sea.
The temperature characteristics of thirty-four European and Mediterranean stations and of thirty Australian stations have been listed and brought together on appropriate tables and diagrams. In general Mediterranean temperatures are later in phase than Australian stations.

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These temperature limits have been projected on a map of the Mediterranean region and the areas corresponding to Australian conditions indicated. These are in general concentrated round the western basin of the Mediterranean Sea.

The temperature characteristics of thirty-four European and Mediterranean stations and of thirty Australian stations have been listed and brought together on appropriate tables and diagrams. In general Mediterranean temperatures are later in phase than Australian stations.

In an earlier communication (1965) it was shown that the cool limits of the cultivation of the grape vine (*Vitis vinifera* L.) in Western Europe were determined by mean monthly temperatures of the warmest monthly period of 65·6° F. (18·7° C.) provided that this was associated with a period of six months during which the mean monthly temperature exceeded 10° C. The isotherm for this warmest monthly period was projected on a map of south-eastern Australia and it was shown that this was in general agreement with Australian experience with the cultivation of *Vitis vinifera*.

Temperature conditions in Australia, however, are such that for useful comparisons, the warmer climates of the Mediterranean region must be taken into account. This is further emphasised by the ready success in Australia of such wine-making procedures as the production of fortified sweet wines, corresponding to the styles of wines of the Douro Valley of Portugal and the *vins doux naturels* of southern France, of *vinos de Jerez* produced in Spain and the Marsala wines of Sicily. This is further exemplified by the production of dried grapes originally characteristic of the Aegean area of Greece and Turkey.

In the maps of Figs. 1 and 2 are shown the important areas under vines in south-eastern and south-western Australia and on these maps are projected the isotherms of the mean annual temperatures for 57° F. and 65° F. and of annual temperature amplitude of 8° F. and 15° F. based on wave-form analysis of the mean monthly temperatures. The annual mean isotherms are adapted from the Climatological Atlas of Australia and the amplitude curves from Prescott (1942).

It will be seen that for south-eastern Australia the viticultural areas fall within these limits which correspond approximately to 65° F. (18·3° C.) and 80° F. (26·7° C.) for the warmest months over the full range of conditions possible within these limits.

The localities in the Mediterranean region with similar temperature limits are illustrated in Fig. 3. In this case the isotherms are adapted from Prescott and Lane-Poole (1947). It will be noted that the areas corresponding to similar ones

[1] Member of the Council of The Australian Wine Research Institute.

in Australia are primary in Portugal, eastern Spain, Morocco, northern Algeria, Tunis and Palestine, together with coastal regions of southern France, Italy, Yugoslavia and Greece and the islands of Sardinia, Corsica and Sicily. The island of Cyprus is too much under continental influences to come within the temperature limits adopted except for very small areas.

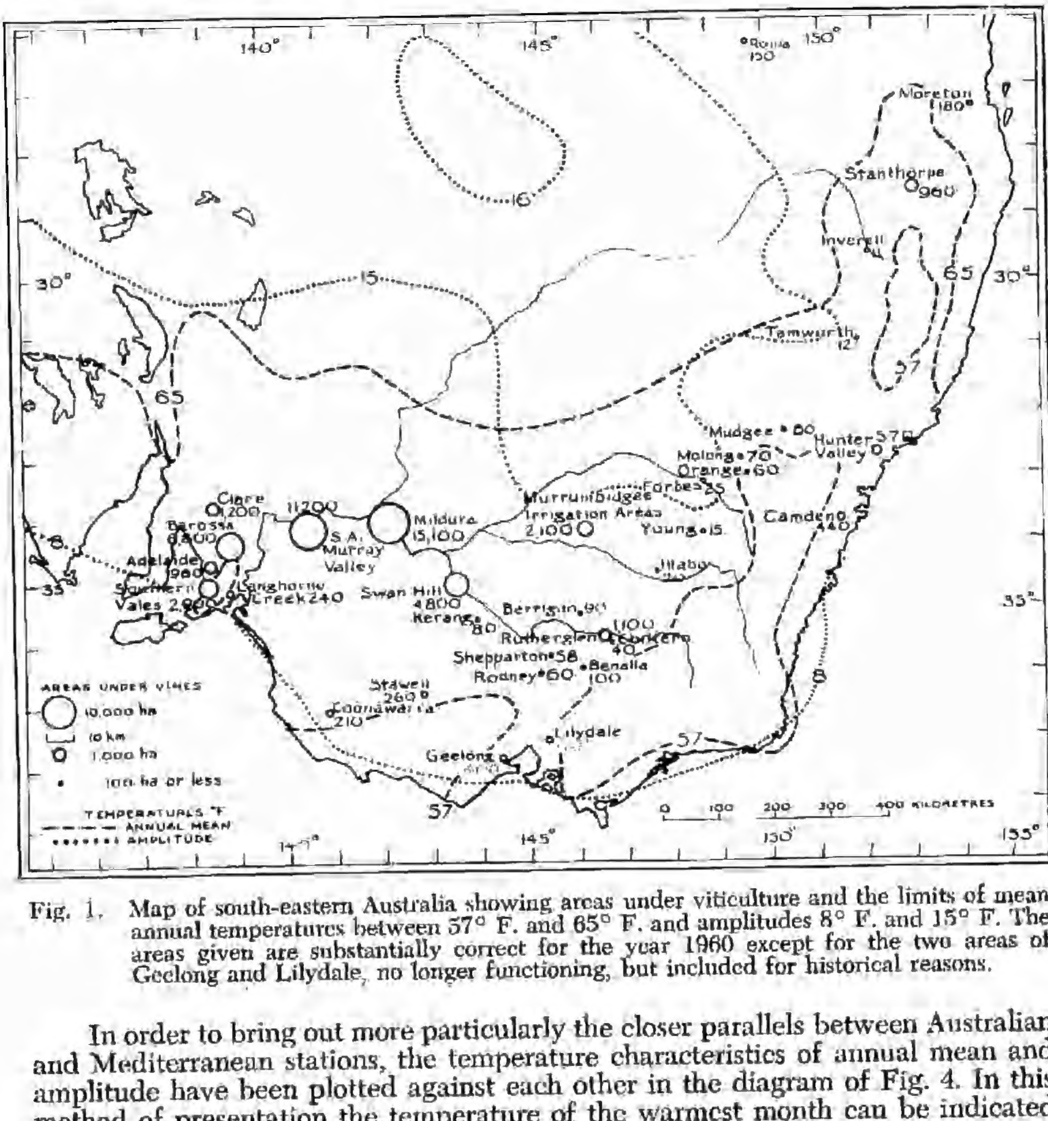


Fig. 1. Map of south-eastern Australia showing areas under viticulture and the limits of mean annual temperatures between 57° F. and 65° F. and amplitudes 8° F. and 15° F. The areas given are substantially correct for the year 1960 except for the two areas of Geelong and Lilydale, no longer functioning, but included for historical reasons.

In order to bring out more particularly the closer parallels between Australian and Mediterranean stations, the temperature characteristics of annual mean and amplitude have been plotted against each other in the diagram of Fig. 4. In this method of presentation the temperature of the warmest month can be indicated by a diagonal line where the sums of the means and amplitudes have a constant value. It will be seen that within the temperature limits adopted, Australian and Mediterranean stations can be readily compared. The stations represented in the preparation of this diagram are listed in Tables 1a and 1b. This table provides a key to the abbreviations used in Fig. 4 and gives latitudes and longitudes and the temperature phase for each station, 64 stations in all. It is noteworthy that this phase value, expressed as lag in days behind solar radiation, is in general much higher for Mediterranean stations than for those in Australia.

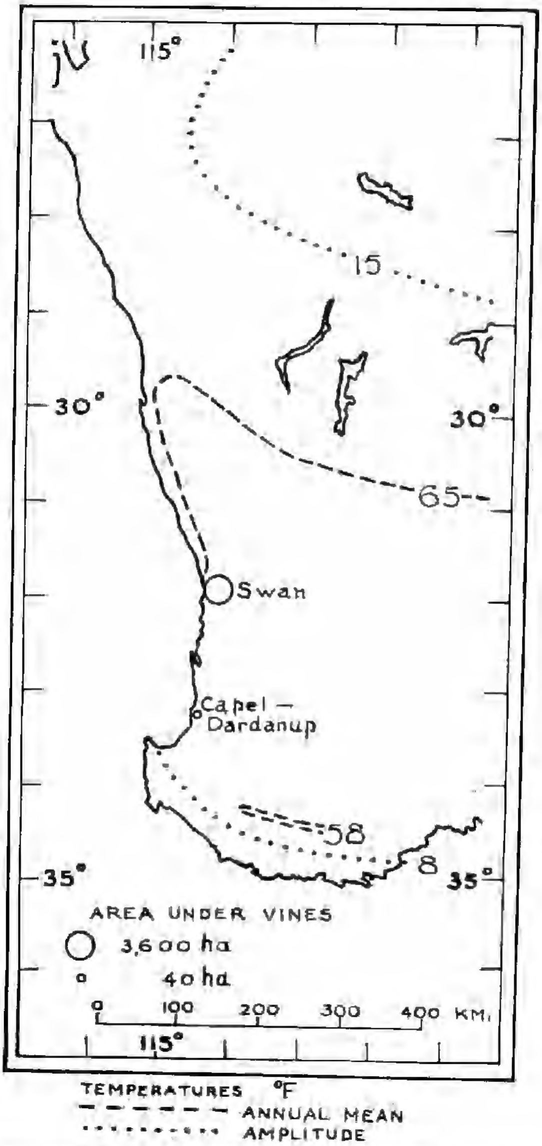
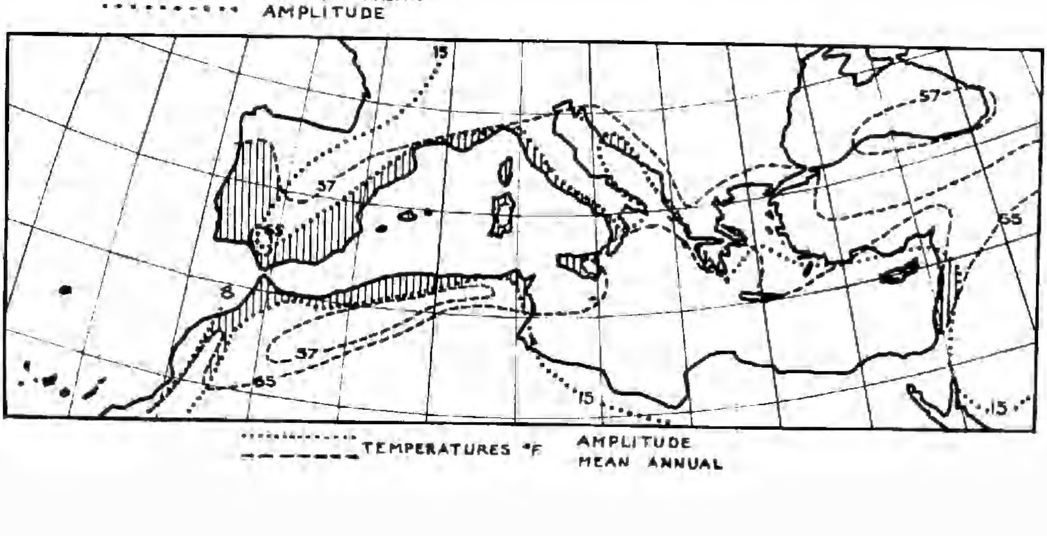


Fig. 2. (*Left*) Map of south-western Australia showing areas under viticulture and the limits of mean annual temperatures between 58° F. and 65° F. and of amplitudes 8° F. and 15° F.

Fig. 3. (*Below*) Map of the Mediterranean region on which have been projected the isotherms of 57° F. (13·9° C.) and 65° F. (18·3 C.) mean annual temperatures and 8° F. (4·4° C.) and 15° F. (8·3° C.) annual amplitudes. Locations which fall within these limits are shaded and have in consequence the temperature conditions prevailing within the zones of Australian viticulture.



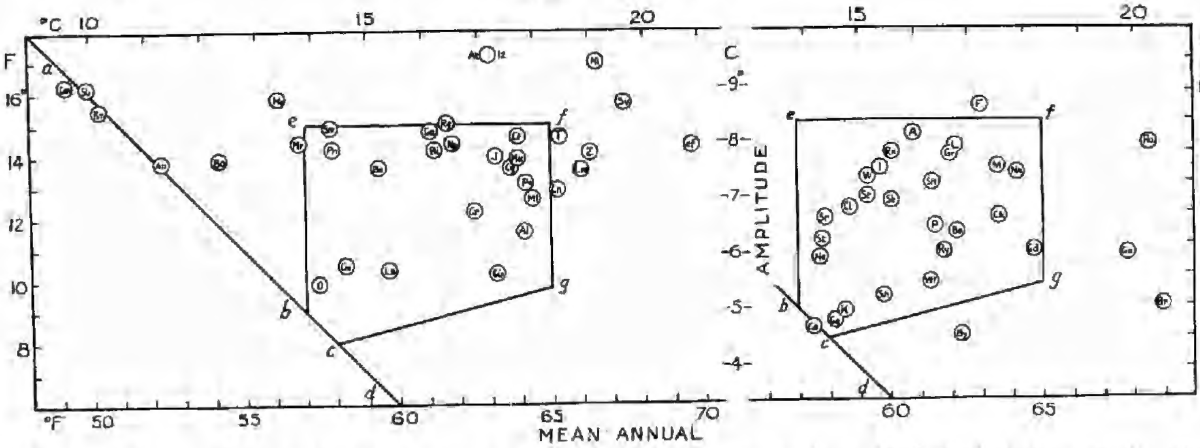


Fig. 4. Diagram illustrating the temperature characteristics (mean and amplitude) of stations in the Mediterranean (left) and Australia (right) regions. The line a.b.c.d. corresponds to a warmest month of 66° F. (18·9° C.). The area defined by e.f.g.c.b. corresponds to the temperature limits of Australian viticultural experience. The key to the abbreviations is given in Tables 1a and 1b. A few European stations near the cool limit of viticulture are included.

TABLE 1a

Information regarding European and Mediterranean stations used in the preparation of Fig. 4

Symbol	Locality	Latitude °N	Longitude °	Lag of temperature behind solar radiation days
Al	Algiers	37·1	3·1 E	47
An	Angers	47·4	0·6 W	29
At	Athens	38·0	23·7 E	39
Ba	Barcelona	41·4	2·2 E	37
Bi	Bari	41·2	16·9 E	43
Bo	Bordeaux	44·9	0·6 W	32
Cg	Cagliari	39·2	9·1 E	43
Cn	Candia	35·3	25·1 E	43
Cr	Cartagena	37·6	0·9 W	42
Cm	Coimbra	40·3	8·4 W	35
Cf	Corfu	39·5	19·9 E	43
eF	El Fayum	29·3	30·9 E	34
Gm	Geisenheim	50·0	8·0 E	26
Ga	Genoa	44·4	8·9 E	40
Gb	Gibraltar	36·2	5·3 W	39
Iz	Izmir	38·4	27·2 E	39
J	Jerusalem	31·8	35·2 E	43
Lm	Limassol	34·6	33·0 E	49
Ls	Lisbon	38·7	9·1 W	39
Ml	Malta	35·8	14·5 E	52
Mr	Marseilles	43·3	5·4 E	33
Mo	Montpellier	43·6	3·9 E	32
Mu	Murcia	38·0	1·1 W	37
Np	Naples	40·8	14·2 E	41
Ni	Nicosia	35·2	33·3 E	40
O	Oporto	41·2	8·6 W	36
Po	Palermo	38·2	13·3 E	43
Pn	Perpignan	42·7	2·9 E	33
Rg	Ragusa	42·6	18·1 E	41
Rm	Reims	49·3	4·0 E	28
Sm	Samsun	41·3	36·4 E	49
Sv	Seville	37·4	6·0 W	35
Sb	Strasbourg	48·6	4·9 E	29
T	Taormina	37·8	15·3 E	42
Z	Zakinthos	37·8	20·9 E	45

TABLE 1b

Information regarding Australian stations used in the preparation of Fig. 4

Symbol	Locality	Latitude °S	Longitude °E	Lag of temperature behind solar radiation at the limits of the atmosphere days
A	Albury	36·1	147·0	27
Be	Berri	34·3	140·6	24
Br	Brisbane	27·5	153·0	27
By	Bunbury	33·3	115·6	41
Ck	Cessnock	32·9	151·4	26
Cl	Clare	33·8	138·6	29
Ca	Coonawarra	37·3	140·9	31
F	Forbes	33·5	148·1	26
Gn	Gatton	27·6	152·3	23
Gg	Geelong	38·1	144·4	34
Gr	Griffith	34·3	146·1	26
Gd	Guildford	31·9	116·0	40
I	Inverell	29·8	151·2	27
K	Kew	37·8	145·0	32
L	Leeton	34·5	146·4	27
M	Mildura	34·2	142·2	25
Nm	Northam	31·7	116·6	35
Na	Nuriootpa	34·5	139·1	31
P	Picton	34·2	150·6	26
Ra	Roma	26·5	148·7	21
Ry	Roseworthy	34·1	138·7	32
Rn	Rutherglen	36·0	146·5	29
Sr	Seymour	37·0	145·1	30
Sh	Shepparton	36·4	145·4	29
St	Stanthorpe	28·6	151·9	24
Sl	Stawell	37·0	142·8	31
Sn	Strathalbyn	35·3	138·9	32
SH	Swan Hill	35·4	143·6	28
WI	Waite Institute	35·0	138·6	33
W	Wangaratta	36·3	146·3	29

To illustrate this point comparisons are made in Fig. 5 between two pairs of Australian and Mediterranean stations, namely Leeton is compared with Naples and Mildura with Cagliari. The differences in phase are clearly indicated in the curves which are based on values calculated from the wave-form characteristics. For a further comparison the curve for Mildura is shown with that of Izmir in Turkey. The annual mean is much the same in each case, but Izmir is already more continental with a much higher amplitude than Mildura. This higher amplitude, together with a late phase leads to higher and later summer temperatures which are of importance to the dried vine-fruit industry.

Station	Temperature characteristics mean ° F.	amplitude ° F.	phase lag behind radiation days
Leeton	62·2	14·2	27
Naples	61·8	14·4	41
Mildura	63·5	13·5	25
Cagliari	63·7	13·6	43
Izmir	63·0	17·2	39

The vertical lines ss correspond to the longest day.

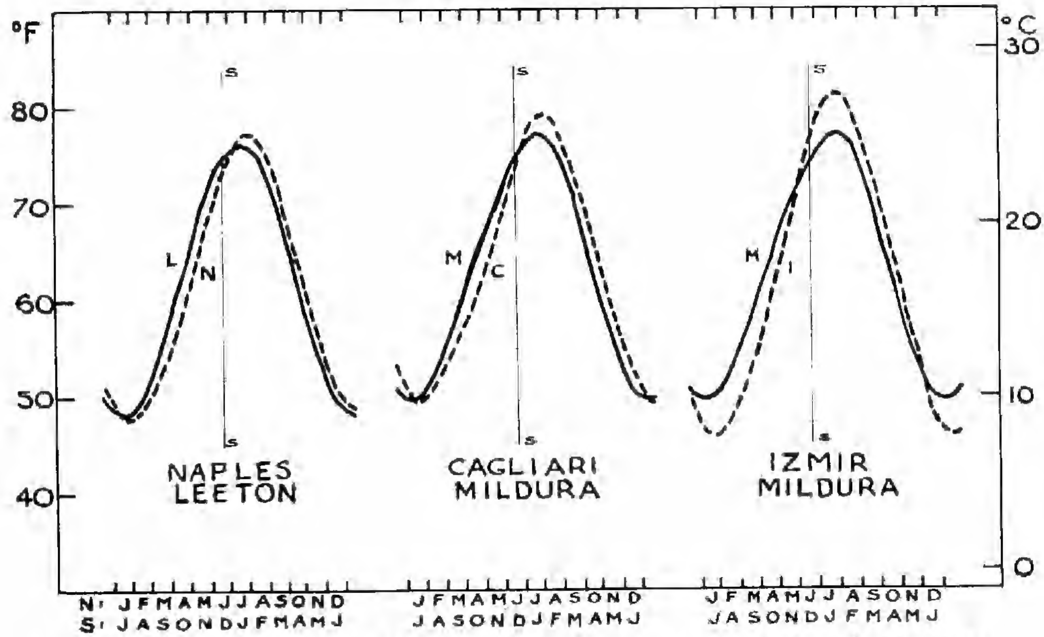


Fig. 5. Temperature curves of stations having comparable temperature characteristics.

ACKNOWLEDGEMENT

Thanks are due to the late Mr. J. C. M. Fornachon, Director of The Australian Wine Research Institute for his interest in the project and for making available correspondence with State Viticulturists who have supplied appropriate statistics from time to time.

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THE CLIMATOLOGY OF THE VINE (*VITIS VINIFERA* L.) [3]
A COMPARISON OF FRANCE AND AUSTRALIA ON THE BASIS OF THE TEMPERATURE OF THE WARMEST MONTH

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The history of climatological investigations on the requirements of the vine in France has been outlined. In order to bring this experience into a wider field of use, it is shown that the temperature of the warmest month can be used as a simple index. This temperature can be expected on mathematical grounds to be a linear function of the sums of temperatures that have been extensively used in the past. This expectation is confirmed by an examination of data for the northern limit of cultivation in Europe, for California in general, and for the classical work of Angot (1885). A brief example is given of the application of this principle to the choice of varieties for any given environment.

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INTRODUCTION

In a previous communication (1969) a comparison was made, on a climatic basis, between the viticultural areas of Australia and their homoclimes in the Mediterranean region. In this comparison, based essentially on the temperature characteristics of annual mean and amplitude, only a small area of France, restricted to the Mediterranean littoral of that country was shown to afford anything approaching a strict parallel to any of the Australian conditions. French experience is so long and so well documented that it is important to find some simple climatic criterion that would extend the application of this experience to a wider geographical range. The most widely used criterion has been the sums of temperatures expressed as day-degrees over a specific group of months, usually the seven months: April to October, or over a specified growth period, such as flowering to maturity. This concept was originally established by de Candolle (1855) where a minimum of 2,900 day-degrees (centigrade) above a limiting temperature of 10° C. was required. The development of this concept in France was principally due to de Gasparin (Cours d'Agriculture vol. 4, 1860) who classified vine varieties into seven groups according to their degree of earliness and who established the "quantities of heat" necessary for the maturation of the grapes in each class. De Gasparin, however, based the maximum temperatures used in the derivation of the mean on the black-bulb thermometer exposed to the sun, so that they cannot be readily interpreted today, and it was Angot (1885) who later pointed out the appropriateness of using shade temperatures.

The study of the climatic limits of viticulture in France has a long history. Arthur Young (1792), in what became edited later as "Travels in France", included a map entitled "a new map of the climate and navigation[2] of France", in which the northern limits of cultivation of vines, maize and olives were shown by straight lines having a north-easterly trend. In the absence of temperature data, these limiting lines were to be regarded as climatic indicators. In a verbal description of the limit for vines Young wrote[3] "the line of separation between vines and

[1] Member of the Council of The Australian Wine Research Institute.
[2] By "navigation" Young meant the navigability of rivers.
[3] loc. cit. p. 298.

no vines, as I observed myself is at Coucy, ten miles to the north of Soissons; at Clermont, in the Beauvoisois; at Beaumont in Maine; and Herbignac, near Guerande in Bretagne". He suggested that it would be reasonable to extend this line into Germany as far north as latitude 52°.[4]

By the second decade of the nineteenth century, a sufficient number of temperature observations over an adequate geographical range had been accumulated to justify the concept and definition of *isotherms* by Humboldt (1817). Although Humboldt did not produce any maps, he provided an extensive table of data from which the trends of isotherms could be judged and, in some cases maps prepared. In this publication Humboldt referred briefly to the possible application of his concepts to agriculture, taking into account not only the annual isotherms, but also the associated mean summer and winter temperatures for any given locality, including specifically the temperatures of the warmest and coldest months. With respect to the cultivation of the vine in Europe he noted that, providing summer temperatures reached 19° C. or 20° C., cultivation could be extended up to a latitude of 50° N. Later in his Kosmos (1845) he was able to give, as a special example, the temperature limits of the vine when cultivated to produce potable wine. These were defined as a mean annual temperature of not less than 9·5° C., a mean winter temperature of at least 0·5° C. and a mean summer temperature of at least 18° C. This mean summer temperature was based on the months of June, July and August, corresponding in modern observations to 17·9° C. and for the warmest month to 18·7° C.

In 1880, the Central Bureau of Meteorology in Paris organised for the first time, the regular observations of vegetation phenomena in France, and at the same time arranged for the collection of such historical information regarding the viticultural seasons and the declaration of vintages (*Ban de vendanges*) as could be derived from municipal and other records. This information was in due course analysed by Alfred Angot (1885), and provided a valuable and unique historical document on climatic conditions in France. The earliest period of vintage recorded was that for 1366 at Dijon and by extending the records to those of Wurtemberg, the quantity and quality of the vintage was established for some years as far back as 1236, while for Burgundy these records began in 1689.

The *ban de vendange* was originally established as a feudal manorial right. This right was abolished in principle in 1791, but was retained as a communal responsibility from that date, in order to guarantee the quality of the best vintages. Long records of the date of the declaration of vintage are to be found in many municipalities and communes and the longest such is for Dijon and goes back with full continuity to 1572.

Of importance to the present study is that Angot was able to correlate the mean period of vintage over a period of 20 years (1860-1879) with temperature observations over the same period, for 22 sets of observations covering mean annual temperatures ranging from 9·0° C. at Gap (Hautes-Alpes) to 15·0° C. at Perpignan (Roussillon). The annual march of temperature was expressed in each case in terms of the constants of a Fourier series (*formule périodique*) where the first two terms of the series proved to be adequate. The commencement of vegetation was assumed to coincide with the time at which mean temperature reached 9° C. and this was calculated from the formula as well as the sums of temperatures between this date and that of the declaration of vintage. For convenience in discussion, these data were placed in seven groups ranging in sums of temperature above 9° C. from 973 to 1957 day-degrees.

[4] John Evelyn in his diary for 1643–44 had earlier observed the north-western limits of the cultivation of the vine at Beauvais and Pontoise.

It is of further interest that Angot was able, by eliminating very early table varieties and very late varieties, and by regrouping, to reduce an original classification of de Gasparin from seven to two groups. These were made up of an early group of varieties able to ripen in the vicinity of Paris and a later group not able to do so. Of interest to Australian vignerons typical varieties in the first group included *Pinot noir*, *Sémillon* and *Shiraz* and the second group included *Malbec*, *Carignan* and *Grenache*.

The assessment of current views and practices has been facilitated by a series of reports commissioned by the *Office international de la vigne et du vin* and presented to the appropriate Commission in September 1967. These reports deal with methods and principles adopted in various countries in determining regional requirements for the culture of the vine and for the choice of varieties. The reports have been published in the Bulletin of the International Office (1967, 1968). In these reports table grapes and wine grapes receive equal emphasis. In some respects, because of the need to cater for markets over as long a period as is practicable, the climatic requirements of table grapes provide a wider range of conditions than do wine grapes, and in most cases the variety *Golden Chasselas* is used as a standard of reference with respect to period of maturity. The earliest table grapes generally include the Hungarian variety *Perle de Csaba* and a number of strains of *Madeleine*. The lists of the latest table varieties usually include the variety *Ohanez*.

The climatic requirements are dealt with in a variety of ways, but practically always the sums of temperatures are used over a fixed period, usually the seven months from April to October, although for Bordeaux, Ribéreau-Gayon and Peynaud (1960) quote the period April to September. These sums are sometimes quoted as above 0° C. and also as "efficient" temperatures above 10° C. In other cases the sums are calculated from the time of bud-burst to that of technical maturity.

The extremes are illustrated by the German report in which only the mean temperature from April to October is quoted, and by the Tunisian report, in which the sums of temperature are calculated as degree-hours over the months March to December. The Israeli report quotes sums of "active" temperatures, that is above 10° C. from bud-burst to maturity over periods varying from 100 days for early varieties to 135 days for very late varieties with the sums ranging from 950 to 1,900 day-degrees, which is very close to the original range of Angot.

Of specific interest to the present study, Brejoux and Daverne in the French report recognise two principal climatic types for that country, namely the Atlantic and Mediterranean, with a semi-continental bridge between the two along the valleys of the Rhine, the Saône and the Rhône.

The relationship between sums of temperature and the temperature of the warmest month

The annual temperature curve of the monthly means for localities within the latitudes determining the limits of the cultivation of *Vitis vinifera* is sufficiently close to a smooth trigonometric curve to suggest that some of the simple properties of such a curve could reasonably be found to be valid. This was early recognised by Angot, as has been mentioned above, and the wave-form characteristics of annual mean, amplitude and phase have frequently been used by the author in climatic studies.

The early recommendation by Humboldt that summer temperatures could be used to establish the geographically cool limit of the vine was statistically confirmed by the author (Prescott, 1965). In terms of the temperature of the warmest month, in both cases this proved to be 18·7° C. Owing to the deciduous

nature of the vine and its winter dormancy, the temperature of the coldest month becomes significant only when damage through frost becomes important.

For a simple cosine curve of temperature, any area beneath the curve, limited by a fixed temperature and within specified time limits can be readily shown to be a linear function of the maximum temperature. Where the critical temperature is one-half of the temperature of the warmest month, there is in fact a strict proportionality between day-degrees and that temperature. For a number of stations along the northern limit of the cultivation of the vine in Europe, the length of the season above 10° C. approximates to 6 months and such a correlation could, in fact, be expected if only approximately. For perfect agreement, the periods for comparison should have the same phase.

In order to illustrate this relationship, three examples have been taken. One example, provided by the data of Angot, previously mentioned, for the period 1860-1879 in which sums of temperatures are calculated from the temperature curves between the time when the temperature first reaches 9° C. and the time of the mean declaration of vintage for these areas. From the wave-form constants quoted by Angot for the temperature curves, it is readily possible to calculate the mean temperature of the warmest month in each case. Angot found it convenient to group his 22 sets of observations into seven and these have been plotted in Fig. 1. It will be seen that an almost perfect rectilinear correlation exists between the pairs of values.

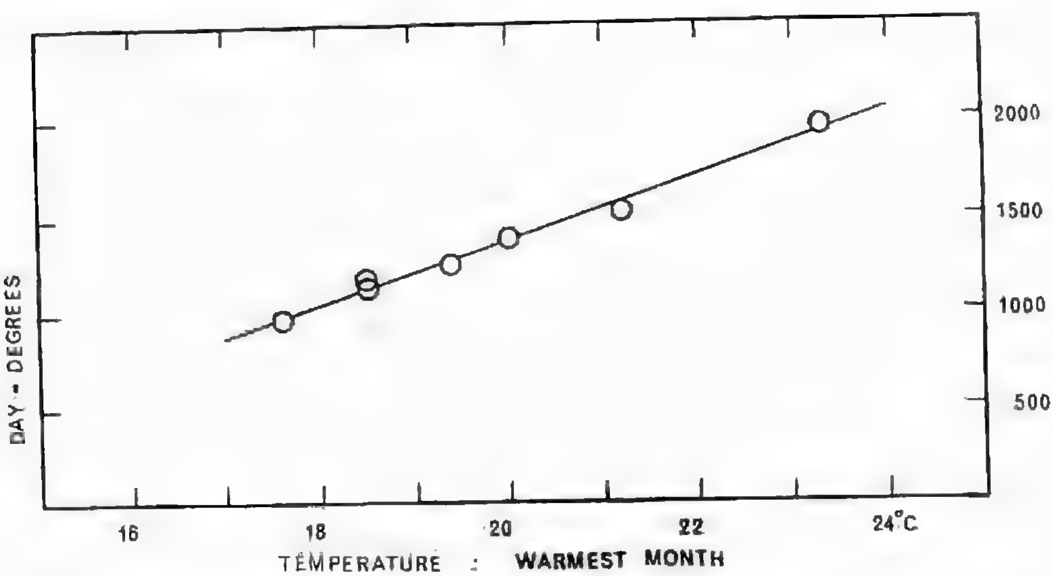

Fig. 1. Illustrating the relationship between the sums of temperature over 9° C. and the temperature of the warmest month. The limits chosen are from the time when the mean daily temperature reaches 9° C., to the time of the average beginning of vintage for groups of French viticultural areas. The data are those of Angot (1885) for the period 1860-1879. The temperatures of the warmest month are derived from estimates of the annual mean plus amplitude based on the Fourier constants given by Angot.

Californian and European experience is drawn upon for the data illustrated in Fig. 2. The Californian data are taken from official records of stations chosen for their viticultural importance. The concept of sums of temperatures has been extensively used by viticultural workers in California, for example, Winkler

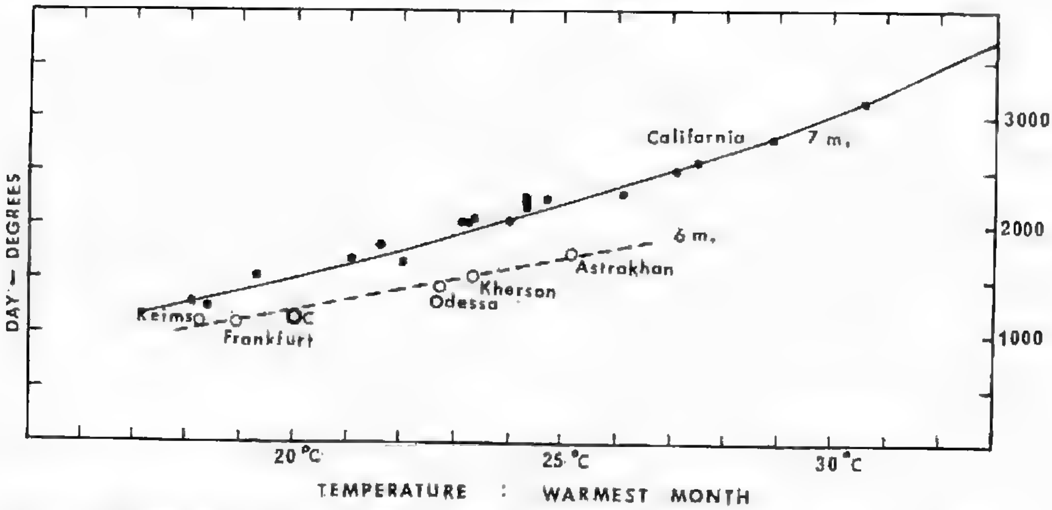

Fig. 2. Illustrating the relationship between the sums of temperatures over 10° C. and the temperature of the warmest month for California and Europe. The California data are based on the months April to October in accordance with current practice. The European data are for the cool limit of cultivation of the vine, using selected stations with season of approximately six months with mean temperatures above 10° C. The circle C represents the theoretical value for a cosine curve (20° C., 1162 day-degrees).

(1962), with particular reference to the subdivision and definition of the viticultural areas of that State into five regions based on temperature summation. The European data are for the cool limit of cultivation as established by the author (1965). In both cases a satisfactory relationship is shown to exist. In the case of the Californian data, the line connecting the pairs of values shows a slight curve.

It should therefore be possible to use the temperature of the warmest month as a substitute for sums of temperatures for general comparisons. The correlation is only valid for mean values over a period of years and cannot be expected to hold for individual seasons. On this basis, however, maps have been prepared for south-eastern Australia and for France, on which the isotherms for the warmest months are shown. This is illustrated in Figs. 3 and 4. The following Table 1 gives a wider perspective to the comparison.

TABLE 1

Temperature of the warmest month for viticultural areas

European and Mediterranean localities	°C	Australian localities
Cool limit of cultivation	19	Geelong (Vic.) Coonawarra (S. Aust.)
Bordeaux (France)	20	
	21	Stawell (Vic.)
	22	Clare (S. Aust.)
Montpellier (France)	23	Rutherglen (Vic.) Berri (S. Aust.)
	24	Griffith (N.S.W.)
	25	Mildura (Vic.)
Tunis (Tunisia)	26	
Izmir (Turkey)	27	
	28	Roma (Qld).
El Fayum (Egypt)	29	
Jordan Valley (Israel)	32	

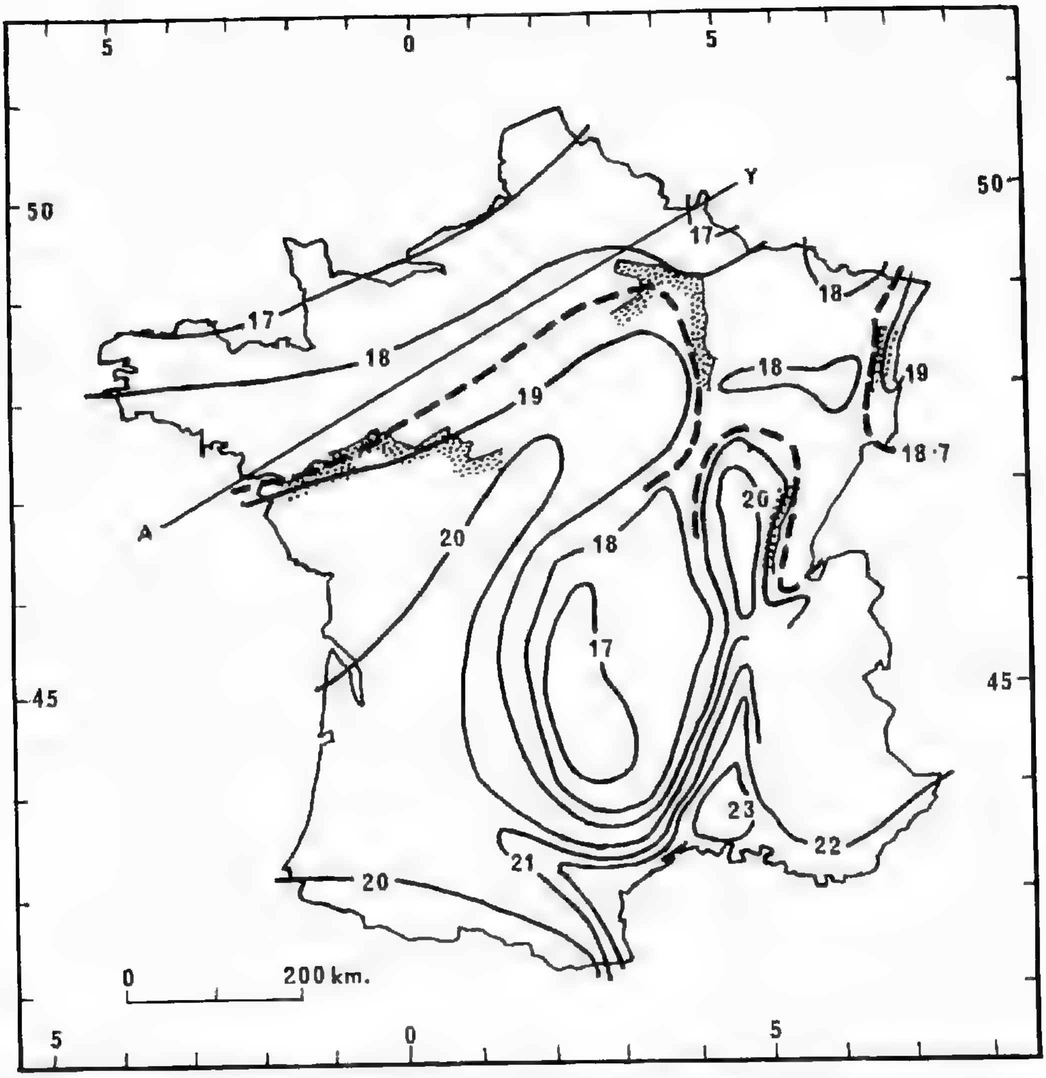

Fig. 3. Map of France with isotherms of the mean temperatures of the warmest month in relation to viticulture. The isotherm for 18·7° C. is based on the cool limit of cultivation in western Europe. The line AY gives the limit recognised by Arthur Young (1792). The stippled margins represent the cool limits of areas recognised for quality by the *Institut national des appellations d'origine* on the map of 1949.

Probably the best example of the use that can be made of the comparison between France and Australia would be in the selection of varieties for any given locality and temperature conditions. It is not intended to present an exhaustive list—this is a task for the experienced viticulturist, but the list in Table 2 may be suggestive in this regard. It will be recalled that Angot divided varieties into two groups, one of which would ripen in the vicinity of Paris and the other not so. The present list may be regarded as an extension of such a concept.

With respect to table grapes, the variety *Chasselas*, which is the most important in France, affords an example of the problems involved in climatological interpretation for such a variety.

TABLE 2

Cool limits for a selection of varieties of vines based on French experience

Temperature of the warmest month °C	Variety
18 — 19	*Chardonnay*
	Chenin
	Gamay
	Pinot noir
	Riesling
	Traminer
19 — 20	*Cabernet gros*
	Cabernet sauvignon
	Malbec
	Syrah (Shiraz)
20 — 21	*Sémillon*
	Trebbiano (Ugni blanc)
21 — 22	*Muscat of Alexandria (Muscat gordo blanco)*
22 — 23	*Carignan*
	Cinsaut
	Grenache
	Mataro (Mourvèdre)

Chasselas first appears in the Paris market in early July from the coastal region of Algeria. This is followed by the crop from the Mediterranean coast of southern France. The main supply comes in late August and in September from the country of the Garonne, with superior quality from near Moissac. Very late supplies come from the region of Paris.

This variety is also used as a wine grape in the semi-continental regions of France and is a recommended variety for certain areas in the Franche-Comté and for Alsace. Under the synonym *Gutedel* it is also used in Germany for wine making. In Baden-Wurtemberg, this variety is grown to the extent of 8·5 percent of the viticultural area.

Constantinescu in the Romanian report points out that certain early varieties do not produce grapes of high quality when grown under warm conditions.

ACKNOWLEDGEMENTS

It is a pleasure to record the help received from the Library of the Royal Society in London in securing copies of the papers by Humboldt and Angot. Thanks are due to Mr. K. M. Cellier and Prof. J. R. Prescott for discussions on the mathematical problems involved and particularly to the late Mr. J. C. M. Fornachon, as director of The Australian Wine Research Institute, for his continued interest in the investigation.

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France	Brejoux, P. and Daverne, P.	40/442	1967	1315-1333
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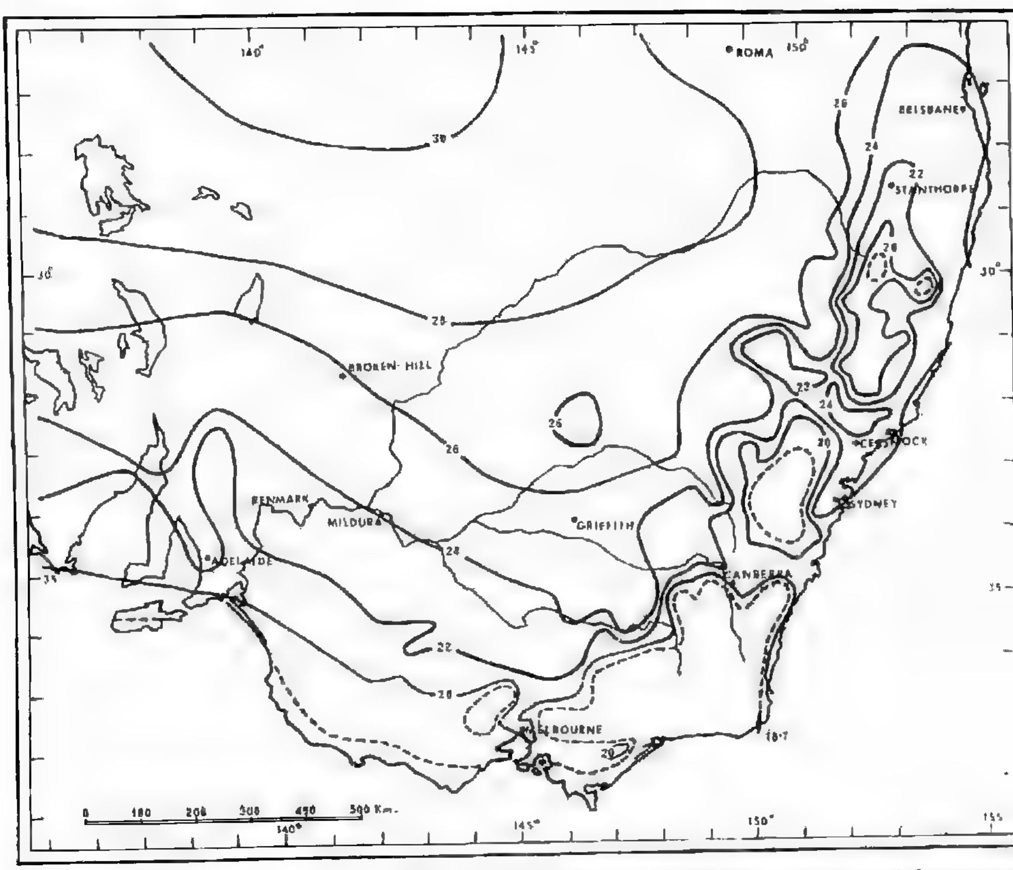

Fig. 4. Map of south-eastern Australia with isotherms of the mean temperatures of the warmest month in relation to viticulture. The isotherm for 18·7° C., represented by a broken line, is based on the cool limit of cultivation of the vine in western Europe.

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A CHECKLIST OF FLOWERING PLANTS OF THE SIMPSON DESERT AND ITS IMMEDIATE ENVIRONS

*BY D. E. SYMON**

Summary

A checklist is given of 353 species of flowering plants from the Simpson Desert and its immediate environs. A total of 180 species has been collected from the sand dune desert proper and an appendix lists 25 species most closely associated with the upper slopes and dune crests. Five species of alien plants *Cenchrus ciliaris* Buffel Grass, *Emex australis* Three Cornered Jack, *Ricinus communis* Castor Oil, *Mulva parviflora* Mallow and *Citrullus colocynthis* Colocinth have been collected to date, all from the general vicinity of Andado Station.

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INTRODUCTION

In 1946 Miss C. M. Eardley published (Trans. R. Soc. S. Aust. *70*, 145) a catalogue of plants collected by the 1939 Simpson Desert Expedition. The list was divided into plants of "the desert proper" (Camp 5 to Camp 19) which was the area covered between the remnants of the Hale River in the north-east and the Mulligan on the eastern edge of the desert. The rest of the list included all other plants collected from the approaches to the desert.

It is obviously not easy to define very precisely this desert within a desert, but the term Simpson Desert is often considered to refer to the great sand dune desert. This receives the Todd, Hale and Hay rivers in the north which give rise to localised water courses and flood plains. On the western side the desert is bordered by the last reaches of the Finke River whose braided remnants thread between the dunes in places. In the vicinity of Andado Station the stony tableland extends into the margins of the desert. On its eastern side the desert is bordered by the Mulligan and Eyre Creek and on the south and south-east by the Kallakoopah and the Warburton above which are many saline and sub-saline claypans and flats.

In the following account many plants from the margins of the desert are included, but those found in the sandridge desert (dunes and flats) and away from marginal intrusions are marked with an asterisk (a total of 180 species). In addition an appendix lists those species most closely associated with the upper slopes of the dunes and the dune ridges, a total of 25 species.

It will be seen that the collecting sites have not been well distributed over the desert and that the areas in the centre, the north-east and the southern margins of the desert have not been well collected.

It has not been possible to examine and check all the many specimens so widely distributed. The list is compiled from the original lists of the Crocker collections, from collecting books supplied by the Alice Springs herbarium, and from lists of the collections made by Lothian and Hill, Boyland, Must and Beauglehole. To all these contributors I am most grateful.

All the species listed are described in Black 1943-1957, or in Eichler 1965 except those few which are individually given a reference to the original source of publication of the name.

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COLLECTORS

The Collectors included in this paper, the areas in which they worked, and their collecting numbers are as follows.

R. L. Crocker crossed the desert with the Simpson Desert Expedition in June 1939 from Andado Station to Birdsville. For details of this journey see Madigan 1945, Crocker 1946, and Eardley 1946, and for an earlier short account of the Simpson Desert and its surroundings see Madigan 1938. The specimens collected are housed at the State Herbarium, Adelaide (AD) and the specimens are quoted by Camp number, e.g. C5. A map of the desert and its surroundings will be found in Madigan 1938, a further map and route of the Expedition in Madigan 1946, and a vegetation map in Crocker 1946.

R. E. Winkworth collected in the north-western part of the desert in October, 1954. His localities and numbers are as follows:

113 km. (70 m.) S.E. of Ringwood Headstation	No. 627–649
113 km. (70 m.) S.E. of Ringwood Window Hill	650–659, 661
64·4 km. (40 m.) S.E. of Ringwood	660
40·1 km. (25 m.) S.E. of Ringwood	662
32·1 km. (20 m.) S.E. of Ringwood	663–670
8·0 km. (5 m.) S.E. of Ringwood	671

N. Forde and *G. M. Chippendale* collected in the north-western parts of the desert in September 1955 using separate numbers.

(A) *N. Forde*

Hale River	1264
6·4 km. (4 m.) N of Nummery H.S.	1265–1266
9·7 km. (6 m.) S of Nummery H.S.	1267
11·3 km. (7 m.) S of Nummery H.S.	1269–1273, 1277–1284
	1292–1293
113 km. (70 m.) S.E. of Ringwood	1274–1276
Window Hill	1285–1291, 1295
1·6 km. (1 m.) S of Nummery H.S.	1296
97 km. (60 m.) S.E. of Ringwood	1297–1300
100 km. (62 m.) S.E. of Ringwood	1301–1310
88 km. (55 m.) S.E. of Ringwood Hale River Crossing	1311–1319
105 km. (65 m.) S.E. of Ringwood	1320–1323
56·3 km. (35 m.) S.E. of Ringwood	1324–1325
32·1 km. (20 m.) S.E. of Ringwood	1326
4·8 km. (3 m.) S.E. of Ringwood	1329

(B) *G. M. Chippendale*

Hale River	1589–1593
97 km. (60 m.) S.E. of Ringwood H.S.	1594–1602
Window Hill	1603–1626
75·7 km. (47 m.) S.E. of Ringwood H.S.	1627–1630
64·4 km. (40 m.) S.E. of Ringwood Hale River	1631–1644
29 km. (18 m.) N.W. of Hale River	1645–1648
22·5 km. (14 m.) S.E. of Ringwood H.S.	1649–1650

G. M. Chippendale visited and collected on the western edge of the desert in September 1956. His sites and collecting numbers follow:

Andado (old head station)	2818
33·7 km. (21·6 m.) N. of Andado	2819–2827
1·3 km. (0·8 m.) N of North Bore, Andado	2828–2829
42·8 km. (26·7 m.) N of Andado H.S.	2830
19·3 km. (12·4 m.) N of Andado H.S.	2831
17·7 km. (11·4 m.) N of Andado H.S.	2832
Andado H.S.	2833
Indinda Bore, Andado	2834, 2836
17·7 km. (11 m.) S.W. of Andado H.S.	2837–2841
22·5 km. (14 m.) S.W. of Andado H.S	2842

23·3 km. (14·5 m.) S.W. of Andado H.S.	2843–2845
46·6 km. (29·2 m.) S.W. of Andado H.S.	2846–2850
91·3 km. (57 m.) S.S.W. of Andado (Boundary Gate)	2851–2852

G. M. Chippendale and *L. A. S. Johnson* revisited the Andado area again in October 1957.

G. M. Chippendale

46·6 km. (29 m.) W of Andado (Old Andado H.S.)	3941–3944
48·6 km. (30·2 m.) N of Andado (North Bore)	3945–3946
20·8 km. (12·9 m.) S of Andado	3947–3949
38·5 km. (24·1 m.) S of Andado	3950–3952
62·8 km. (38·8 m.) N.E. of Charlotte Waters	3953

G. M. Chippendale revisited the Simpson Desert again in 1958 and 1959; September 1958—northern area.

0·8 km. (0·5 m.) N.W. Hale River near Simpson Desert	4927
Bottom Bore, Nummerie, Hale River	4928–4930
11·8 km. (7·3 m) S.E. Bottom Bore Hale River	4931
12·5 km. (7·8 m.) S.E. Bottom Bore Hale River	4932
14·5 km. (9 m.) S.E. Bottom Bore Hale River	4933–4935
20·9 km. (13 m.) S.E. Bottom Bore Hale River	4936–4937, 4952
27·3 km. (17 m.) S.E. Bottom Bore Hale River	4938
30·6 km. (19 m.) S.E. Bottom Bore Hale River	4939–4941
41·8 km. (26 m.) S.E. Bottom Bore Hale River	4942
53·1 km. (33 m.) S.E. Bottom Bore Hale River	4943–4945, 4948
58·0 km. (36 m.) S.E. Bottom Bore Hale River	4946–4947
62·8 km. (39 m.) S.E. Bottom Bore Hale River	4949
63·6 km. (39·5 m.) S.E. Bottom Bore Hale River	4950–4951
17·7 km. (11 m.) S.E. Bottom Bore Hale River	4953
12·9 km. (8 m.) S.E. Bottom Bore Hale River	4954
20·9 km. (13 m.) Ringwood H.S.	4955–4962

Andado again in September, 1959—western edge.

127·5 km. (79 m.) N of Andado H.S.	6574–6582
121·0 km. (73 m.) N of Andado H.S.	6583–6587
109·9 km. (68 m.) N of Andado H.S.	6588–6589
105·0 km. (65 m.) N of Andado H.S.	6590–6592
100·2 km. (62 m.) N of Andado H.S.	6593–6594
92·9 km. (58 m.) N of Andado H.S.	6595–6598
74·1 km. (46 m.) N of Andado H.S.	6599–6603
61·2 km. (38 m.) N of Andado H.S.	6604
74·1 km. (46 m.) S.W. of Andado H.S.	6605–6609

T. R. N. Lothian and *R. Hill* collected on the western edge of the desert approximately due east of Dalhousie Springs Station on road made by the French Oil Search Company between August 9-12 1963. Their base camp was just within the borders of the dune desert.

Base Camp between dunes 3–4	1407–1508
Gibber plain between dunes 2–3	1509–1530
Flats between dunes 3–4	1531–1592
30·6 km. (19 m.) E of base camp, high dunes, deep valleys, deep sand	1593–1622
48·3 km. (30 m.) E of base camp, flat between dunes, little or no sand	1623–1656
48·3 km. (30 m.) E of base camp, dunes, deep sand	1657–1700
35·3 km. (22 m.) E of base camp, sand dunes	1701–1753
16·1 km. (10 m.) E of base camp, sand	1754–1763
35·3 km. (22 m.) E of base camp, sand	1764–1775
9·7 km. (6 m.) E of base camp consolidated sand, slopes and flat	1776–1781
Base camp	1782
11·3 km. (7 m.) E. of base camp then 2 m. along dune trough, consolidated sand	1783–1831
3·2 km. (2 m.) E of base camp, clay pan between dunes	1832–1860
Gibber plain between dunes 3–4	1861–1870
Dune No. 3 near base camp	1871–1885
Gibber plain at base camp	1886–1898

D. Boyland collected on the S.E. corner of the desert in September 1966.

74·1 km. (46 m.) S.S.E. of Poeppel Corner, sandy clay near salt lake	230–233
48·3 km. (30 m.) S.S.E. of Poeppel Corner, interdune flat	234
Poeppel Corner, sandy clay on salt lake	235–236
Poeppel Corner, sandy soil edge of salt lake	236A–245
Poeppel Corner, sandy soil interdune flat and slopes	246–286
144·8 km. (approximately 90 m.) W.N.W. of Birdsville	287–293
113·0 km. (approximately 70 m.) W.N.W. of Birdsville	294–297
89·7 km. (approximately 56 m.) W.N.W. of Birdsville	298–322

D. Symon collected at the Amerada Petroleum Corporation No. 1 Hale River drilling site at 25° 15′ 50″S, 136° 43′ 35″E in November 1966. This area is approximately 129 km. (80 m.) W of the Queensland border and 129 km. (80 m.) E of Andado Station and is almost in the centre of the great sand dune desert. Collecting numbers 4331-4405.

Mr. A. C. Beauglehole of Portland, Victoria, collected in the Andado Station area in July 1968. One set of his specimens has been sent to the herbarium at Alice Springs and duplicates of some other genera have been distributed as follows:

Bassia and *Zygophyllum* at AD, State Herbarium, Adelaide, and
Cassia and *Solanum* at ADW, Waite Herbarium, Adelaide.

For brevity his collections are cited as ACB and his collecting sites and numbers are as follows:

109·7 km. (68·2 m.) N.N.W. of Old Andado H.S., 1·6 km. (1 m.) N.N.W. of Bench mark 394	27751–27764
106·7 km. (66·3 m.) N.N.W. of Old Andado H.S., 1·4 km. (·9 m.) S.S.E. of Bench mark 394	27774–27796
103·7 km. (64·5 m.) N.N.W. of Old Andado H.S., about Bench mark 395	27796A–27843
91·7 km. (57 m.) N.N.W. of Old Andado H.S., 1·6 km. (1 m.) N.N.W. of Bench mark 398	27843A–27878
75·6 km. (47 m.) N.N.W. of Old Andado H.S., bore and dam at Bench mark 69/41, 400	27885–27890
69·5 km. (43·2 m.) N.N.W. of Old Andado H.S., 4·3 km. (2·7 m.) S.S.E. of Bench mark 401	27893–27894
53·2 km. (33·2 m.) N.N.W. of Old Andado H.S., 9·0 km. (5·6 m.) N.N.W. of Bench mark 404	27900–27908
42·1 km. (26·2 m.) N.N.W. of Old Andado H.S., 2·2 km. (1·4 m.) S.S.E. of Bench mark 404	27910–27911
30·2 km. (18·8 m.) N.N.E. of Old Andado H.S., about 16·1 km. (10 m.) N.N.E. of Bench mark 408	27916–27928
17·2 km. (10·7 m.) N.N.W. of Old Andado H.S., about Bench mark 408	27930–27946
Old Andado H.S. area	27947–27967
15·3 km. (8·9 m.) W. of Old Andado H.S., 5·0 km. (3·1 m.) E. of New Andado H.S.	27976–28015A
3·2 km. (2 m.) W. of New Andado H.S.	28016–28033B
43·4 km. (27 m.) S.W. of New Andado H.S., 1·6 km. (1 m.) N.E. of mill and bore	28034–28037

Miss J. Must, Mr. D. Nelson and *Mr. J. R. Maconochie* of the Animal and Agriculture Industry Branch of the Northern Territory Administration, Alice Springs, collected at a site 22-27 km. (14-17 m.) north of Andado homestead in July and August 1968. The collection is listed under the collecting numbers of Miss Must. The specimens are deposited at the herbarium at Alice Springs (NT) with some duplicates at ADW. The area is outside the stony tablelands and is right in the dune system. The collecting numbers and dates are as follows:

Miss J. Must	Nos. 48–119	11.7.1968
	Nos. 314–342 . . .	8–12.8.1968

The specimens collected by Winkworth, Forde and Chippendale are mainly at the Herbarium at Alice Springs (NT) (Northern Territory) but with many

duplicates at Canberra. The specimens of Crocker, Lothian and Hill are at the State Herbarium Adelaide (AD), those collected by Symon are at the herbarium of the Waite Institute (ADW) with duplicates at AD and elsewhere. The specimens collected by Boyland are at the State Herbarium, Brisbane (BRI).

FLOWERING PLANTS OF THE SIMPSON DESERT AND ITS IMMEDIATE ENVIRONS

CHECKLIST

(* = plants found in the actual sandridge desert)

TYPHACEAE

Typha domingensis Pers. Leafy specimen only of this aquatic herb. ACB. 27963.

RUPPIACEAE

Ruppia spiralis L. ex Dum. An aquatic plant from channel of the Hale River. Crocker (as *R. maritima*).

JUNCAGINACEAE

Triglochin calcitrapa Hook. A small erect annual. Lothian 1533. ACB.27839, 27906, 27924.

Triglochin calcitrapa var. *isingiana* Black. A small erect annual. Chippendale 2841; Lothian 1533. ACB.27906, 28002.

Triglochin centrocarpa Hook. A small erect annual. These three *Triglochins* are all closely related. ACB.27931, 28008.

POACEAE (Gramineae)

**Aristida contorta* F. Muell. (*A. arenaria* Gaud.). An annual or short-lived perennial collected on hard soil on an interdune flat. Lothian 1546, 1631, 1862, Must 55, 341.

**Aristida browniana* Henr. An annual or short-lived perennial often a dominant grass on flats and slopes between the dunes, widely collected. Crocker C1, C3; Chippendale 1600, 6578; Lothian 1676, 1747, 1827; Boyland 266, 313; Symon 4379; Must 53; ACB.27756.

Brachiaria milliformis (Presl.) Chase. A short-lived perennial. ACB.27780.

Brachiaria praetervisa (Domin) Hubbard. An annual grass from the flood plain of the Hale River. Crocker.

Cenchrus ciliaris L. An alien perennial pasture grass. ACB.27965.

Chloris acicularis Lindl. A tall perennial grass apparently rare in the desert. Forde 1291. ACB.27855.

Chloris pectinata Benth. A tussock perennial grass. ACB.27997.

Cynodon dactylon (L.) Pers. A stoloniferous perennial. ACB.27959.

Dactyloctenium radulans (R.Br.) Beauv. A sprawling annual, not common here, collected from interdune claypan flats. Lothian 1583, 1835, 1860. ACB.27784, 27833, 27911, 28014.

**Danthonia bipartita* F. Muell. A perennial tussock grass. Must 58, 320.

Dichanthium humilius J. M. Black. A small tufted annual, not common. Crocker C3; Forde 1295.

Dichanthium sericeum (R.Br.) Camus. An erect perennial tussock grass. Lothian 1850.

Digitaria ammophila (F. Muell.) Hughes. A tufted perennial grass. Winkworth 654; Lothian 1558.

Digitaria brownii (R. and S.) Hughes. A tussock perennial, locally common on a rock outcrop. Winkworth 636; Must 337.

Diplachne fusca (L.) Beauv. An erect perennial tussock grass. Crocker (As *D. muelleri*); Lothian 1542, 1559; ACB.27805, 27998.

**Enneapogon avenaceus* (Lindl.) Hubbard. An annual grass from interdune flats or in deep red sand. Crocker; Chippendale 6579; Lothian 1571, 1627, 1858; ACB.27802.

**Enneapogon cylindricus* Burbidge. An erect tufted perennial from sandy soil on an interdune flat. Lothian 1570; Boyland 259; Must 57.

**Enneapogon polyphyllus* (Domin.) Burbidge. Common or occasional on flats between the dunes. Crocker C3; Chippendale 1622; Symon 4346.

Eragrostis concinna Steud. An annual, very variable in size. ACB.27828, 27990.

**Eragrostis dielsii* Pilger. A prostrate annual or short-lived perennial occasional on deep red sand from interdune flat areas. Crocker C2, C3; Chippendale 6580; Lothian 1803, 1829, 1833, 1864; Boyland 236; ACB.27810, 27977.

**Eragrostis eriopoda* Benth. A tough tussocky perennial very common on the flats and slopes and in places a dominant grass. Crocker C8, C16; Symon 4347, 4383; Must 330, 332; ACB.27846.

Eragrostis kennedyae F. Turner. A tussock perennial. ACB.27993.

**Eragrostis laniflora* Benth. A tussock perennial on some interdune flats. Crocker C1; Winkworth 630; Lothian 1715.

Eragrostis leptocarpa Benth. A slender annual, variable in size. ACB.27801, 27843, 28009.

**Eragrostis setifolia* Nees. A tussock perennial similar in plant form to the two species above, collected from clayey sandy soil on an interdune flat. Crocker C3; Forde 1293; Chippendale 2824; Lothian 1569; Boyland 300; ACB.27776, 27803.

**Eragrostis xerophila* Domin. A perennial tussock grass. Must 51, 336.

**Eriachne aristidea* F. Muell. An erect annual common on the upper slopes and crests of the sand ridges and on deep sand. Crocker C2; Chippendale 1624; Lothian 1462, 1666, 1753, 1800, 1816; Boyland 260; Symon 4348; Must 338; ACB.28013.

Eriachne benthamii Hartley. A perennial tussock grass. ACB.27996.

Eriachne helmsii (Domin) Hartley. Rare on loose sandy soil in interdune areas. Winkworth 658.

Iseilema eremaeum Blake. A small annual grass. Lothian 1574.

Neurachne muelleri Hack. Must 323.

**Panicum australiense* Domin. A small tufted annual not common. Crocker (as *Ichnanthus*); Symon 4377.

Panicum decompositum R.Br. A tussock perennial from interdune clay flat. Crocker C3; Winkworth 653.

**Plagiosetum refractum* (F. Muell.) Benth. An annual common and widespread along the upper slopes and dune crests, widely collected. Crocker; Forde 1269, 1276; Chippendale 6587, 6609; Lothian 1617, 1677, 1697, 1736, 1792; Boyland 311; Symon 4357; Must 325; ACB.27864.

**Setaria* sp. (? *S. brownii* Herrm. in Rosen, Beitr. Biol. Pflanzen 10:61 (1910)). An annual grass. Crocker C18; Forde 1298.

Sporobolus actinocladus (F. Muell.) F. Muell. An erect annual or short-lived perennial. ACB.27982.

Tragus australianus Blake. A small sprawling annual grass. Lothian 1573, 1831; ACB.27831.

**Triodia basedowii* Pritzel. A widespread, pungent leaved, hummocky perennial, very common on flats and slopes and one of the dominant grasses of the desert. Crocker C8, etc.; Lothian 1468; Boyland 314; Symon 4382; Must 52; ACB. 27858.

Tripogon loliiformis (F. Muell.) Hubbard. A small tufted perennial. ACB. 27827.

**Triraphis mollis* R.Br. An annual common or occasional on flats and dune slopes. Crocker C3; Forde 1271; Chippendale 1599; Lothian 1412, 1463, 1503, 1636, 1748, 1801, 1863; Boyland 234; Symon 4389; Must 56; ACB. 27757, 27795.

**Zygochloa paradoxa* (R.Br.) Blake. A perennial forming a tough tangled clump, a dominant grass and important sand binder on the upper slopes and ridges of the dunes. Many other plants get some shelter from this widespread species. Crocker C3; Winkworth 631; Forde 1272; Chippendale 1596, 2833; Lothian 1459, 1661, 1883; Boyland 279; Symon 4360; Must 59; ACB.27754.

CYPERACEAE

Cyperus bulbosus Vahl. A perennial sedge, producing small bulbils. Crocker C3, C4.

Cyperus gilesii Benth. A graceful annual sedge. ACB.27992.

Cyperus iria L. An annual sedge. ACB.27989.

Cyperus squarrosus L. A small erect annual sedge. Crocker C4, etc. (As *C. aristatus* Benth.); ACB.28004.

Fimbristylis dichotoma (L.) Vahl. A tufted perennial, apparently rare in the desert. Crocker C19; ACB.27813, 28010.

CENTROLEPIDACEAE

Centrolepis polygyna (R.Br.) Hieron. A very small annual. ACB.28007.

LILIACEAE

**Anguillaria dioica* R.Br. A small erect bulbous plant. ACB.27979; Must 69.

**Bulbinopsis semibarbata* (R.Br.) Borzi. An annual or ephemeral apparently rare on hard clay flats between dunes. Lothian 1493, 1578, 1652, 1857; ACB.27835, 27902.

Corynotheca lateriflora (R.Br.) Benth. An unexpected record, the specimens are not ideal and more material is needed for confirmation. On deep interdune sands. Lothian 1671, 1680.

PROTEACEAE

**Grevillea juncifolia* Hook. A large shrub or small tree (3 m.) occurring on interdune flats. In 1966 many were dead as a result of the long drought, but many new seedlings were seen. Crocker C6-S; Lothian 1477, 1701, 1720; Boyland 319; Symon 4365, 4392.

**Grevillea stenobotrya* F. Muell. A medium sized (1-1·5 m.) shrub, occasional on the interdune slopes. Crocker C5, C6, C7, C12, C13; Symon 4366.

**Grevillea striata* R.Br. A small tree apparently rare in interdune areas. Crocker C5; Winkworth 645.

**Hakea divaricata* Johnson. (*H. intermedia* Ewart and Davies). A small tree, apparently rare. Crocker C7, C10; Boyland 317; Must 110.

**Hakea leucoptera* R.Br. A shrub or small tree in open grassland. Crocker C1, C2, C8; Winkworth 663; Forde 1299; Lothian 1469; Boyland 251.

SANTALACEAE

Santalum lanceolatum R.Br. A shrub or small tree very rare in the desert. Crocker C3; Winkworth 637; Boyland 312.

LORANTHACEAE

Amyema maidenii (Blakely) Barlow. A parasite on *Acacia aneura* and *cambagei*. Crocker (as *Loranthus maidenii*) C3; Boyland 288.

Lysiana exocarpi (Behr.) Tiegh. Parasite on *Acacia peuce*. Crocker (as *Loranthus exocarpi*); Chippendale 2829 (lost or mislaid).

Lysiana spathulata (Blakely) Barlow. Parasite on *Acacia kempeana*. Forde 1279 (as *Loranthus exocarpi* var. *spathulata*); ACB.27764, 27821.

POLYGONACEAE

Emex australis Steinh. An alien annual herb. ACB.27959.

Muehlenbeckia cunninghamii (Meisn.) F. Muell. An intricate tangled sprawling shrub often associated with waterways and flood plains. Crocker; Lothian 1874; Boyland 309; ACB.27820.

Rumex crystallinus Lange. An erect annual or short-lived perennial. ACB. 27955.

CHENOPODIACEAE

Atriplex angulata Benth. A small perennial shrub on a flood plain. Chippendale 2827; ACB.27920.

Atriplex campanulatum Benth. A sprawling herb. ACB.27995.

Atriplex conduplicata F. Muell. Austral. J. Pharm. 429 (1886). A small shrub or herb on flood plain. Chippendale 2826.

Atriplex crassipes J. M. Black. A small erect annual or short-lived perennial. ACB.27916.

Atriplex elachophylla F. Muell. A small annual in the shelter of trees and in red sand. Winkworth 652; Chippendale 1621.

Atriplex fissivalvis F. Muell. A small herb on stony gibber flat. Lothian 1865.

Atriplex holocarpa F. Muell. A small herb on flood plain or interdune flat. Chippendale 2852, 3950; Lothian 1549.

**Atriplex limbata* Benth. A sprawling herb on interdune flats. Lothian 1421, 1711; Boyland 248.

Atriplex lindleyi Moq. An annual herb. Forde 1333.

Atriplex muelleri Benth. Sprawling annual herb. ACB.27961.

Atriplex nummularia Lindl. A perennial shrub 1-3 m. tall on flood plain or stony interdune flat. Chippendale 2851, 4937; Lothian 1523.

**Atriplex spongiosa* F. Muell. An annual herb in depressions or on stony plain. Chippendale 3951, 4952; Lothian 1549; Boyland 238; ACB.27819.

Atriplex velutinella F. Muell. A sprawling annual or short-lived perennial. ACB.27938.

**Atriplex vesicaria* Heward ex Benth. A shrubby perennial collected from stony rises or interdune flats. Crocker C2; Forde 1313, 1318; Lothian 1650; Chippendale 1639, 1642, 1643, 4941; Boyland 233, 245.

Babbagia acroptera F. Muell. and Tate. A small perennial shrub collected from stony or hard interdune flats. Crocker C20; Lothian 1528, 1638, 1844.

Babbagia dipterocarpa F. Muell. A small perennial shrub locally common on flood plain and rare on stony plain. Chippendale 2819, 3946; ACB.27939.

Bassia andersonii Ising. A perennial herb infrequent on stony plain in clayey red soil. Chippendale 3942; ACB.27824.

**Bassia bicornis* (Lindl.) F. Muell. A small shrub from clayey sandy soil of interdune flat. Crocker, Chippendale 6591; Lothian 1526, 1554; Boyland 320; ACB.27818.

Bassia calcarata Ising. A small sprawling undershrub. ACB.27917.

Bassia convexula Anderson. A small grey shrub common in red sandy flat. Winkworth 650; Chippendale 3939; Must 85; ACB.27886.

Bassia cornishiana F. Muell. A woolly leaved, spiny fruited perennial. Must 108.

Bassia decurrens Black. A compact small shrub. ACB.27980.

**Bassia diacantha* (Nees) F. Muell. A sprawling annual or short-lived perennial from hard soil on interdune flats. Crocker; Lothian 1644, 1649, 1708; Boyland 240; ACB.27823.

Bassia divaricata (R.Br.) F. Muell. A small shrub locally common in sandy soil in shelter of trees. Chippendale 4960; Lothian 1525.

**Bassia eremaea* Ising. A small shrub from interdune flat. Lothian 1645

Bassia eriacantha (F. Muell.) Anderson. A small shrub from stony areas. Forde 1315; Chippendale 3948; Lothian 1887.

**Bassia intricata* Anderson. Locally common on flood plain and on stony red soils, a small intricate shrub. Crocker; Chippendale 2825, 3941, 4918; Lothian 1525, 1562; Boyland 239.

Kochia aphylla R.Br. An intricate small shrub occasional on interdune flood plain. Chippendale 2830; Lothian 1890; ACB.27799.

Kochia coronata J. M. Black. A small sprawling shrublet locally common on flood plain. Chippendale 2822, 3943; Lothian 1527; ACB.27918.

Kochia georgei Diels. A small stout shrub on stony rise and plain, locally common. Forde 1314, 1328; Chippendale 1640, 2843, 3949; Lothian 1888.

**Kochia lanosa* Lindl. A small sprawling shrub, apparently not common. Crocker C11.

Kochia microcarpa (Benth.) Wilson. A sprawling short-lived perennial. ACB. 28020.

Kochia spongiocarpa F. Muell. A dwarf grey shrub, rare in clayey red soil on stony plain. Chippendale 3944.

Kochia tomentosa F. Muell. A small shrub infrequent near small stony watercourse. Crocker C3; Forde 1323; Chippendale 4959.

Kochia triptera Benth. A small shrub. ACB.27787.

**Pachycornia tenuis* (Benth.) Black. A small intricate shrub from sandy soil at the edge of a salt lake. Crocker C2; Chippendale 2831, 4943; Boyland 241; ACB.27816.

**Rhagodia spinescens* R.Br. var. *deltophylla* (F. Muell.) Black. A sprawling shrub on deep firm sand or dune slopes. Crocker; Lothian 1444, 1812; Symon 4370; ACB.27788.

**Salsola kali* L. and var. *strobilifera* Benth. An intricate rounded annual from deep sands. Crocker C2, C5; Lothian 1512, 1513, 1561, 1647, 1871; Boyland 246; Symon 4400; Must 86; ACB.27763.

Threlkeldia proceriflora F. Muell. An erect undershrub. ACB.27919.

**Bassia johnsonii* Ising. An intricate perennial undershrub on swale flats. Must 107; ACB.27861.

**Bassia lanicuspis* (F. Muell.) F. Muell. A dwarf shrub, locally common on stony rise to infrequent in sandy loam. Forde 1316, 1321; Chippendale 1641, 4962; Lothian 1514, 1555, 1642, 1646, 1648; ACB.27809.

**Bassia paradoxa* (R.Br.) F. Muell. An annual or small, short-lived shrub occasional in sandy loam to common on stony interdune flat. Crocker; Chippendale 1628, 4961, 6590; Lothian 1411, 1557, 1866; ACB.27826.

Bassia parallelicuspis Anderson. An annual or small shrub on interdune flat. Lothian 1548, 1556.

**Bassia quinquecuspis* (F. Muell.) F. Muell. A small shrub or annual from interdune flats. Chippendale 3940; Symon 4394 (as var. *villosa*).

**Chenopodium auricomum* Lindl. An erect small shrub, locally common on flood area. Forde 1329; Chippendale 2834; Boyland 299; ACB.27941, 27956.

Chenopodium cristatum (F. Muell.) F. Muell. A small prostrate annual from interdune flats. Lothian 1446, 1471; ACB.27830, 27967.

**Chenopodium plantaginellum* (F. Muell.) Aellen. in Engl. Jahrb. 63:487 (1930). From heavy soil near salt lake. Boyland 237.

Dysphania myriocephala Benth. A small prostrate annual. ACB.27837, 28011.

**Enchylaena tomentosa* R.Br. An intricate and sprawling small shrub from sandy interdune flats. Crocker C8, C9; Boyland 247; Must 49; ACB. 27753.

AMARANTHACEAE

**Amaranthus grandiflorus* (J. M. Black) J. M. Black. An annual herb, apparently not common, from deep interdune sands. Crocker C11; Lothian 1452, 1502, 1599; Must 333; ACB.27794.

Amaranthus mitchellii Benth. An erect annual herb. ACB.27791.

**Ptilotus atriplicifolius* (A. Cunn. ex Moq.) Benl. in Mtt. Bot. Staatssamml. Munchen 2:404 (1958). Collected from heavy deep sands. Lothian 1662, 1806, 1895.

Ptilotus exaltatus Nees. Stout, erect, perennial herb from a sandy watercourse. Crocker C2.

Ptilotus helipteroides (F. Muell.) F. Muell. A small annual herb from a rocky outcrop near a creek bank. Crocker C4; Winkworth 668; Chippendale 1647.

**Ptilotus latifolius* R.Br. Very common along the upper slopes of the steep dune face and a primary coloniser of the mobile crests. It can form large (75 cm.) showy white, rounded herbs. Widespread and repeatedly collected. Crocker C10; Chippendale 2816, 6602, 6605; Lothian 1410, 1485, 1615, 1729, 1797, 1818; Boyland 291; Symon 4355; Must 75; ACB.27863, 27930.

Ptilotus nobilis (Lindl.) F. Muell. Rare in the desert, in stony ground at the base of hills. Chippendale 4955.

**Ptilotus obovatus* (Gaudich) F. Muell. An undershrub most common on stony plains and slopes, rarely if ever found on deep sand. Crocker; Winkworth 632; Chippendale 1612, 2845, 4958, 6597; Lothian 1893; Must 81.

**Ptilotus polystachyus* (Gaudich) F. Muell. (*P. alopecuroideus*) and including the form *rubriflorus*. Depending on season a small or large sprawling herb which may be 1 m. high by 2 m. wide. It may be very common on deep sand on the flats and dune slopes. Widespread and widely collected. Crocker C1, C2, C14; Winkworth 649; Chippendale 1623, 6582; Lothian 1433, 1540, 1614, 1653, 1688, 1730, 1805; f. *rubriflorus* 1435, 1490, 1731, 1804; Boyland 283; Symon 4401; Must 80; ACB.27857.

NYCTAGINACEAE

**Boerhavia diffusa* L. A prostrate annual or perennial herb, on hard interdune flats. Crocker C3; Winkworth 655; Lothian 1634.

GYROSTEMONACEAE

Codonocarpus cotinifolius (Desf.) F. Muell. A short-lived tree very rare in the desert. A single tree recorded by Crocker near the Hay River.

°*Gyrostemon ramulosus* Desf. A short-lived shrub or small tree. Must 112, 329; ACB.27845.

AIZOACEAE

Aizoon quadrifidum (F. Muell.) F. Muell. An intricate rounded small shrub. ACB.27976.

Glinus lotoides L. A sprawling herb. ACB.27954.

°*Trianthema pilosa* F. Muell. A sprawling mat-forming herb locally common on deep sand flats and slopes. Crocker C2; Lothian 1422, 1445, 1473, 1607, 1696, 1745, 1757, 1826; Symon 4345; Must 116.

Trianthema triquetra Willd. A prostrate annual herb on hard flats between dunes. Lothian 1521, 1885.

TETRAGONACEAE

Tetragonia eremaea Ostenf. A prostrate annual herb from hard stony interdune flats. Lothian 1518, 1580.

PORTULACACEAE

Calandrinia species frequently make most unsatisfactory herbarium specimens due to their extreme succulence and tendency to fall to pieces on drying with the result that accurate determinations are often difficult.

°*Calandrinia balonensis* Lindl. A succulent ephemeral locally common on deep sand between dunes. Symon 4395; Boyland 302; Must 324, 100.

°*Calandrinia disperma* J. M. Black. A sprawling fleshy annual. Must 113.

°*Calandrinia polyandra* Benth. A succulent ephemeral locally common on deep sand. Symon 4396; Must 106.

Calandrinia ptychosperma F. Muell. A prostrate annual rare in the desert on an interdune flat. Lothian 1532; ACB.27838.

Calandrinia pumila (F. Muell. ex Benth.) F. Muell. A small annual also rare in the desert on an interdune flat. Lothian 1537; ACB.27829.

Calandrinia cf. *remota* Black. A succulent annual or ephemeral. Lothian 1505, 1619, 1710, 1762; ACB.27847.

°*Portulaca intraterranea* J. M. Black. A sprawling mat-forming herb up to 1 m. across, common on the consolidated sides of dunes and lower slopes. Crocker C2; Winkworth 642; Chippendale 1614; Lothian 1451, 1486, 1506, 1618, 1687, 1691, 1751, 1872; Boyland 263, 322; Symon 4397; Must 339.

Portulaca oleracea L. A small mat-forming succulent herb on interdune flats. Lothian 1502 p.pt. 1592; ACB.27891.

BRASSICACEAE (CRUCIFERAE)

°*Arabidella eremigena* (F. Muell.) Shaw. An annual herb from clayey sandy soil on an interdune flat. Boyland 295 (as *Blennodia eremigena*).

Arabidella procumbens (Tate) Shaw. A slender prostrate annual. ACB.27908.

°*Blennodia canescens* R.Br. An annual herb from the sides of a dune. Winkworth 634; Must 67.

°*Blennodia pterosperma* (Black) Black. An annual herb common along the upper slopes of the dunes and forming a fringe along the sides of the unstable crests. Crocker C11; Chippendale 1610; Boyland 281; Symon 4358; Must 65.

°*Harmsiodoxa blennodioides* (F. Muell.) Schulz. An annual herb from interdune flats. Boyland 303 (as *Blennodia lasiocarpa*).

Lepidium muelleri-ferdinandi Thell. A small annual only once collected from an interdune flat. Lothian 1551.

°*Lepidium rotundum* DC. A small annual herb on interdune flats. Chippendale 6581; Lothian 1427, 1443, 1496, 1589, 1819; Boyland 258; Symon 4332; Must 114.

°*Stenopetalum lineare* var. *canescens* Benth. An erect annual herb from hard interdune flats. Lothian 1418, 1581, 1626, 1655, 1773, 1848; Must 77.

CRASSULACEAE

Crassula colorata (Nees) Ostenf. A very small succulent annual. Lothian 1531; ACB.27991.

PITTOSPORACEAE

Pittosporum phylliraeoides DC. An erect shrub or small tree from small creek-line, often colonial. Forde 1326; Chippendale 1650.

MIMOSACEAE

Acacia aneura F. Muell. ex Benth. A small tree on stony interdune flat. Winkworth 628; Lothian 1565; Must 101.

°*Acacia brachybotrya* Benth. A shrub on sand or interdune flat. Boyland 254.

°*Acacia brachystachya* Benth. A tree on consolidated interdune sands. Crocker C2; Lothian 1809.

°*Acacia cambagei* R. T. Baker. A tree on sandy flat, flood plain. Crocker; Boyland 249.

°*Acacia dictyophleba* F. Muell. A colonial shrub or small tree on deep sand slopes or ridges, one of the most widespread species in the desert. Crocker C6, C7; Chippendale 4951; Lothian 1442, 1467, 1491, 1604, 1694, 1743; Boyland 256; Symon 4375; Must 99.

Acacia estrophiolata F. Muell. A slender, graceful, small or large tree infrequent on deep sand or flats. Crocker C3; Chippendale 4953, 6589.

Acacia georginae F. M. Bailey. Bot.Bull. 13:9. A tree locally common in sandy loam of flood plain. Chippendale 1590, 4936.

Acacia kempeana F. Muell. A large shrub locally common on ridge. Crocker C2; Chippendale 1604; Must 96.

Acacia leptopetala Benth. A shrub or tree. Forde 1265.

°*Acacia ligulata* A. Cunn. ex Benth. A colonial, large or small shrub. One of the commonest species in the desert, on deep sand on flats and on dune slopes. Crocker C1, C2, C6; Forde 1284; Chippendale 4930; Lothian 1431, 1488, 1612, 1663, 1721, 1724; Boyland 252; Symon 4359, 4367.

°*Acacia linophylla* W. V. Fitzgerald. A tall shrub from interdune flats. Lothian 1441, 1498, 1664, 1718, 1791.

°*Acacia maitlandii* F. Muell. (*A. patens* F. Muell. ex Benth.) A shrub. Crocker C6, C8.

°*Acacia murrayana* F. Muell. ex Benth. A large shrub or small tree on deep sand. Crocker C6; Chippendale 2847, 4928, 6583; Lothian 1472, 1593, 1667; Boyland 253, 289; Must 331.

Acacia peuce F. Muell. An erect tall tree restricted in distribution to near Andado on the stony plain and also found near Birdsville. Crocker; Chippendale 2828, 3945.

°*Acacia ramulosa* W. V. Fitzgerald. A large shrub or small tree from interdune sands. Boyland 292.

Acacia sessiliceps F. Muell. A shrub to 3 m. rare on floodout. Chippendale 1633.

°*Acacia tetragonophylla* F. Muell. A large shrub or small tree. Lothian 1782; Boyland 316.

Acacia victoriae Benth. An intricate small or large tree locally common on stony flat. Winkworth 638; Forde 1327; Chippendale 1649; Lothian 1508.

Acacia ? wattsiana F. Muell. ex Benth. A small shrub. Crocker C17.

CAESALPINIACEAE

Bauhinia carronii F. Muell. A tree from the Eyre Creek, Kaliduwarry Station. Crocker C20.

**Cassia nemophila* Vogel. A woody shrub 1-2 m. tall, at times colonial in habit, on the lower slopes of the dunes or on the interdune flats. Crocker C7, C14; Chippendale 4933, 6595; Lothian 1424, 1492, 1713, 1764; Boyland 308; Symon 4405; Must 97; ACB.27812, 27862.

**Cassia nemophila* var. *zygophylla* (Benth.) Symon. A medium sized shrub. Symon 4384; Must 50, ACB.27850.

Cassia oligophylla F. Muell. A woody shrub. Chippendale 1603, 4957, 6596; Lothian 1896; ACB.27790, 27848, 27878.

**Cassia pleurocarpa* F. Muell. A shrub, usually low (to 1 m.), at times colonial and widespread on the interdune flats and dune slopes. Crocker C1, C10, C13; Forde 1294; Chippendale 1626; Lothian 1456, 1670, 1733; Boyland 318; Symon 4368; Must 98; ACB.27874.

Cassia pruinosa F. Muell. A straggly shrub usually found on rocky or stony sites. Chippendale 1635.

FABACEAE (PAPILIONACEAE)

**Crotalaria cunninghamii* R.Br. A stiffly erect annual or short-lived shrub common along the upper steep slopes of the dunes and in the edge of the loose sand on the crests. Widespread and commonly collected. Crocker C8; Winkworth 627; Forde 1268; Chippendale 1594, 6600; Lothian 1776; Boyland 255; Symon 4356; Must 94; ACB.27870.

**Crotalaria dissitiflora* Benth. An annual or short-lived willowy herb also found along the upper slopes of the dunes and in deep sand. Widespread and commonly collected. Crocker C8, C15; Forde 1273; Chippendale 1607, 4938; Lothian 1413, 1432, 1487, 1622, 1657, 1702, 1777, 1796, 1807, 1877; Symon 4379; Must 88; ACB.27856, 27950, 28034.

**Crotalaria eremaea* F. Muell. Rep.Greg. Pl.5. Collected from the lower slopes of sand ridges. Boyland 270.

Crotalaria mitchellii Benth. A spreading prostrate perennial on loamy soil. Lothian 1534.

**Crotalaria novae-hollandiae* DC. A perennial herb in sandy loam between ridges. Chippendale 4931, 1616; Lothian 1824.

Crotalaria strehlowii Pritz. A perennial herb, apparently rare on sandridge crest. Crocker; Chippendale 6608.

Glycine canescens Herm. A slender twining herbaceous perennial. Lothian 1409.

**Indigofera brevidens* var. *uncinata* Benth. Small perennial shrubs. ? Winkworth 646; Lothian 1682, 1704, 1721; Symon 4391; ACB.27935.

Isotropis wheeleri F. Muell. ex Benth. A small slender shrub. Must 48.

Lotus cruentus Court. A prostrate annual herb. Crocker; Lothian 1588, 1839, 1859; ACB.27943.

Psoralea cinerea Lindl. An erect annual. Crocker C20.

**Psoralea eriantha* Benth. Annual or perennial herb of variable size to 1 m. high along the base of the steep face of the dunes or in deep sand. Crocker C14, C20; Lothian 1454, 1660, 1716, 1727, 1813; Boyland 278; Symon 4362; Must 322.

**Psoralea patens* Lindl. An erect herbaceous perennial from interdune claypan. Lothian 1840; Chippendale 4932; Boyland 286; ACB.28016.

Ptychosema trifoliatum F. Muell. A procumbent slender herb. Must 73.

Sesbania cannabina (Retz.) Poir. A slender erect herb. Crocker C20 (as *S. aculeatus*).

Swainsona burkittii F. Muell. ex Benth. From the desert margin only, a sprawling perennial. Forde 1308.

Swainsona flavicarinata Black. Sprawling herb in deep sand. Chippendale 1619, 1630; Lothian 1511, 1568, 1867, 1892.

**Swainsona microphylla* ssp. *affinis* A. Lee. A small branching herb on the slopes on deep sand. Crocker C6, C7; Symon 4341; Must 76.

Swainsona oligophylla F. Muell. ex Benth. A prostrate annual herb. ACB. 28018.

Swainsona oroboides F. Muell. A small annual or herbaceous perennial. Forde 1292.

**Swainsona parviflora* Benth. Fl. Austral. 2:223. Collected from sandy clay edge of salt lake. Boyland 230.

**Swainsona phacoides* Benth. Prostrate spreading annual on interdune flats. Crocker C2; Chippendale 1602, 2850, 6584; Lothian 1428, 1765, 1783, 1815, 1843, 1868; Boyland 271; ACB.27933.

**Swainsona rigida* (Benth.) Black. At first a delicate willowy herb, later more intricate and rigid, along the dune crests. Crocker C17; Lothian 1621, 1659, 1672, 1725; Boyland 290; Symon 4386.

**Tephrosia* affin. *purpurea* (L.) Pers. A locally common perennial herb along the upper slopes of the dunes. Crocker; Boyland 282; Symon 4371.

Tephrosia remotiflora F. Muell. ex Benth. Must 51, 76B.

**Tephrosia sphaerospora* F. Muell. A perennial herb on the interdune flats. Chippendale 4946; Lothian 1429, 1799, 1830, 1876.

Trigonella suavissima Lindl. A small sprawling annual. Lothian 1519; ACB. 27923.

GERANIACEAE

Erodium aureum Carolin. A sprawling annual herb. Lothian 1417, 1639, 1656, 1856; ACB.27806.

Erodium cygnorum Nees. A vigorous sprawling annual. Forde 1320; Lothian 1817; ACB.28024.

**Erodium cygnorum* ssp. *glandulosum* Carolin. Chippendale 1644; Lothian 1501, 1587, 1628, 1772, 1849; Boyland 310; Must 60.

ZYGOPHYLLACEAE

**Nitraria schoberi* L. A large intricate sprawling shrub from sandy clay near edge of salt lake. Boyland 232.

**Tribulus hystrix* R.Br. A prostrate annual on the upper slopes of the dunes. Chippendale 1606; Lothian 1712; Boyland 280.

**Zygophyllum ammophilum* F. Muell. An annual herb occurring on the flats or floodouts. Chippendale 1593; Lothian 1416, 1457, 1484, 1633, 1654, 1753, 1821, 1845; Symon 4385; Boyland 244; Must 105; ACB.27871, 27962.

Zygophyllum compressum J. M. Black. An erect annual herb. Crocker C20.

**Zygophyllum howittii* F. Muell. An annual herb from sandy flats. Crocker C2; Forde 1303; Lothian 1453, 1504, 1613, 1690, 1709, 1759, 1788, 1808; Boyland 243; Symon 4404; ACB.27752, 27926.

Zygophyllum iodocarpum F. Muell. A diffuse bushy annual. Lothian 1517.

EUPHORBIACEAE

°*Adriana hookeri* (F. Muell.) Mueller-Arg. An erect dioecious perennial herb from interdune flats. Crocker C5, C8; Symon 4369, 4350.

°*Euphorbia drummondii* Boiss. A quite prostrate herb on the flats and slopes. Chippendale 3954; Lothian 15 numbers; Boyland 285, 293; Symon 4364; Must 117, 335; ACB.27865, 27894, 28035.

°*Euphorbia eremophila* A. Cunn. ex Hook. An erect herb, probably annual. Chippendale 1618; Lothian 1408, 1810, 1873, 1891; Boyland 321; Must 102.

°*Euphorbia wheeleri* Baill. A semi-erect sprawling herb often partially engulfed in sand on the dune slopes where it appears to replace *E. drummondii*. Crocker C11; Boyland 262; Symon 4376; Must 104.

°*Glochidion rhytidospermum* (Mueller Arg.) Eichler (as *Phyllanthus rhytidospermum*). A small annual from interdune flats in sand. Winkworth 640; Chippendale 1609, 4945; Boyland 265.

°*Glochidion trachyspermum* (F. Muell.) Eichler (as *Phyllanthus trachyspermus*). A small annual. Lothian 1476, 1497, 1596, 1707, 1738.

°*Phyllanthus fuernrohrii* F. Muell. A small shrub on flats and slopes. Chippendale 4944, 6586; Boyland 306.

Ricinus communis L. An alien shrub or small tree often confined to drainage lines in the arid areas. ACB.27964.

STACKHOUSIACEAE

Stackhousia viminea Sm. A slender erect herbaceous perennial. Forde 1309; Lothian 1464.

SAPINDACEAE

Atalaya hemiglauca (F. Muell.) F. Muell. ex Benth. A small tree, not common in the desert and locally found on a dune crest. Winkworth 633.

°*Dodonaea attenuata* A. Cunn. A shrub from sandy soil on interdune flats. Chippendale 4950; Boyland 284; Must 326; ACB.27872.

°*Dodonaea viscosa* Jacq. A shrub or small tree. Crocker C12; Lothian 1723.

TILIACEAE

°*Triumfetta winneckeana* F. Muell. Winnecke Re. (1884) 15. A perennial creeping herb from the dune ridges. Crocker C6, C7, C8.

MALVACEAE

°*Abutilon otocarpum* F. Muell. An erect herbaceous perennial or undershrub, fairly widely collected from deep interdune sands. Winkworth 659; Forde 1281; Lothian 1598, 1780; Symon 4331; ACB.27859.

Hibiscus farragei F. Muell. An erect shrub, rare in the desert and only collected once on a flood out. Chippendale 1592.

°*Hibiscus krichauffianus* F. Muell. A small shrub from dune slopes. Crocker C1 etc.; Chippendale 2848; Lothian 1750, 1779.

°*Lavatera plebeia* Sims. A perennial herb. Crocker C20; Boyland 301A.

Malva parviflora L. An alien annual herb. ACB.27951.

°*Sida corrugata* Lindl. A variable small shrub on interdune flats. Crocker C20; Chippendale 1613; Boyland 250; Symon 4373; ACB.27775.

°*Sida cunninghamii* White. A small undershrub. Lothian 1698, 1837; Boyland 257.

Sida platycalyx F. Muell. ex Benth. A small undershrub, not common on inter-dune area. Crocker C1-2; Winkworth 639; ACB.27786.

Sida trichopoda F. Muell. A small undershrub collected from a floodplain. Chippendale 2823; ACB.28019.

**Sida virgata* Hook. A small erect shrub, variable, from interdune flats and slopes. Crocker C13; Chippendale 1625; Lothian 1470; Symon 4378; ACB.27984.

STERCULIACEAE

Gilesia biniflora F. Muell. A small prostrate perennial apparently rare in the desert. Lothian 1832.

Melhania oblongifolia F. Muell, (*M. incana*). A small shrub, not common, in deep sands. Crocker C2; Forde 1300, 1310; Chippendale 1629.

FRANKENIACEAE

**Frankenia gracilis* Summerh. A small undershrub locally common on stony hillslope on desert margins. Chippendale 1589, 4927; Boyland 235; ACB. 27936, 27978.

HALORAGACEAE

**Haloragis gossei* F. Muell. An erect annual on interdune deep sands. Crocker C9-10; Lothian 1706, 1719; Symon 4372, 4387; Must 317.

**Haloragis heterophylla* Brongn. A small perennial colonial herb. Crocker C3; Boyland 304.

Myriophyllum verrucosum Lindl. An aquatic plant from the Hale River channel. Crocker.

APIACEAE (UMBELLIFERAE)

Daucus glochidiatus (Labill.) Fisch. Mey. and Ave-Lall. A small erect annual, not common. Lothian 1576, 1838; ACB.28006.

**Trachymene glaucifolia* (F. Muell.) Benth. An erect annual, variable in size, common on flats and slopes in deep sand. Crocker (as *Didiscus*) C2; Winkworth 657; Chippendale 6588; Lothian nine numbers; Boyland 264; Symon 4337; ACB.27759, 27779, 27877.

CONVOLVULACEAE

**Convolvulus erubescens* Sims. A prostrate herb, annual or perennial. Crocker C3; Chippendale 4954; Lothian 1510, 1564, 1651, 1855; Must 115. ACB. 27781.

**Evolvulus alsinoides* L. A small erect perennial subshrub apparently rare. Forde 1282; Lothian 1448, 1760; ACB.27778.

**Ipomoea heterophylla* R.Br. A prostrate herbaceous perennial. Lothian 1449, 1802.

**Ipomoea muelleri* Benth. A sprawling vine. Crocker C3, C15.

VIOLACEAE

Hybanthus enneaspermus (L.) F. Muell. A small undershrub described as infrequent on stony hillside. Chippendale 1634.

THYMELAEACEAE

**Pimelea trichostachya* Lindl. A small erect annual. Lothian 1420, 1500, 1705.

MYRTACEAE

Eucalyptus—None of the following Eucalypts (small or large trees) are common in the sand dune desert and most are confined to flood plains and river remnants as they peter out in the desert.

Eucalyptus dichromophloia F. Muell. Chippendale 1605.

**Eucalyptus microtheca* F. Muell. Crocker (As *E. coolabah*) C6, C7, C12, C13, C16; Forde 1319; Boyland 298.

Eucalyptus papuana F. Muell. Forde 1290.

**Eucalyptus terminalis* F. Muell. Crocker (as *E. pyrophora*) C3, C17, C18; Forde 1296; Must 93.

Melaleuca glomerata F. Muell. A small shrubby tree which like the Eucalypts above is largely confined to creeklines, rare in the desert. Chippendale 1637.

**Thryptomene maisonneuvii* F. Muell. A small intricate shrub apparently rare. Crocker; Must 84.

BORAGINACEAE

Heliotropium asperrimum R.Br. A colonial herbaceous perennial. ACB.27985.

**Heliotropium pleiopterum* F. Muell. An erect annual or short-lived perennial. Must 118, 327.

Omphalolappula concava (F. Muell.) Brand. A small erect annual. Lothian 1516.

Plagiobothrys plurisepalus (F. Muell.) Johnston. A small prostrate annual herb. ACB.27904.

**Trichodesma zeylanicum* (Burm.f.) R.Br. A stiff erect annual or short-lived perennial from a few centimetres to a metre high, common on deep sand on flats or slopes. Chippendale 1595, 4947, 6599; Lothian 1435, 1494, 1683, 1732, 1793, 1880; Symon 4374; Boyland 277; Must 83, ACB.27868.

CHLOANTHACEAE

A small family of shrubs. Examination of the herbarium specimens at AD and ADW suggests considerable confusion in their identification and when they are revised or more rigorously checked the following names may be changed.

Dicrastylis costelloi F. M. Bailey. A subshrub to 45 cm., rare in deep red sand between ridges. Chippendale 3955.

**Dicrastylis doranii* F. Muell. including var. *eriantha*. Colonial small shrub occasional on interdune flats. Crocker C16-17; Lothian 1600, 1700, 1722; Symon 4342, 4388; ACB.27853.

Newcastelia cephalantha F. Muell. A rounded small shrub. Crocker C17.

Newcastelia spodiotricha F. Muell. A shrub or herbaceous perennial. ACB. 27852.

LAMIACEAE (LABIATAE)

Teucrium racemosum R.Br. An erect perennial herbaceous herb. Crocker C20; Forde 1330; Chippendale 2836; Boyland 307; ACB.27960.

SOLANACEAE

Datura leichhardtii F. Muell. ex Benth. An annual, infrequent in floodout. Chippendale 1632.

Nicotiana ingulba J. M. Black. An erect annual herb. Must 82.

Nicotiana velutina Wheeler. An erect annual herb locally common. Crocker C20, Chippendale 1615, 2832; Lothian 1499, 1641, 1771; Boyland 276; ACB.27910, 27958.

**Solanum chenopodinum* F. Muell. An erect, perennial, colonial undershrub, in interdune areas often under shade or shelter. Crocker C19; Forde 1289; Chippendale 1620.

**Solanum coactiliferum* J. M. Black. A small colonial undershrub. Crocker C14.

**Solanum ellipticum* R.Br. A sprawling colonial subshrub from interdune sands. Crocker C5; Chippendale 4956; Must 79.

**Solanum esuriale* Lindl. A small herbaceous colonial perennial. Crocker C16; Must 90; ACB.27948.

Solanum quadriloculatum F. Muell. A small shrub collected from flood out. Chippendale 1591; ACB.27876.

Solanum sturtianum F. Muell. An erect, colonial, perennial, often associated with creeklines in arid areas. Chippendale 3947.

SCROPHULARIACEAE

Limosella australis R.Br. A very small sub-aquatic herb. ACB.28015A.

°*Morgania glabra* R.Br. An erect perennial herb usually near water or creeklines. Crocker C5; Chippendale 4949; ACB.27825, 27889, 27940.

Peplidium muelleri Benth. A sprawling herb. Lothian 1536; ACB.27903, 27905, 28003, 28005.

ACANTHACEAE

Rostellularia pogonanthera F. Muell. (*Justicia procumbens* non L. Robertson in Black 1957.) A small spreading erect perennial, along small watercourse. Winkworth 667; Forde 1324; Chippendale 1645.

Ruellia corynotheca F. Muell. ex Benth. Fl.Austral. 4:546. A perennial herb or subshrub, not common. Forde 1325; Chippendale 1646.

MYOPORACEAE

Eremophila a genus of shrubs well developed in the arid areas of Australia. They range in size from smallish intricate shrubs flowering when only 20 cm. high to small trees.

Eremophila duttonii F. Muell. A small shrub common but scattered between sand ridges. Chippendale 6594; ACB.27807.

Eremophila freelingii F. Muell. A shrub to 2 m., common on a hill. Chippendale 1608; Lothian 1889.

°*Eremophila latrobei* F. Muell. A grey shrub to 2 m, on rocky or hard soil. Crocker C2, C5, C18; Chippendale 1636; Lothian 1643; Must 334.

°*Eremophila longifolia* (R.Br.) F. Muell. An erect colonial shrub or small tree. Crocker C3, C7, C8; Lothian 1466, 1640, 1714, 1884; Boyland 297; Symon 4398; Must 92; ACB.28017.

°*Eremophila macdonnellii* F. Muell. A small shrub with grey foliage and fine purple flowers, common in deep sands. Crocker; Chippendale 1627, 4940, 6601; Lothian 1637, 1742; Boyland 287; Symon 4351, 4363; ACB.27849.

Eremophila maculata (Ker-Gawl) Muell. A shrub to 1 m. locally common in loamy soil. Chippendale 4942; ACB.27798, 28029.

Eremophila obovata L. Smith Proc.Roy.Soc.Q. 1956: 75, 33. A subshrub in deep red sand. Chippendale 1617, 2842; Must 91.

°*Eremophila strehlowii* E. Pritzel. A small shrub. Crocker C12, C13.

°*Eremophila strongylophylla* F. Muell. Apparently rare. Crocker C2, C5.

°*Eremophila willsii* F. Muell. An erect shrub. Crocker C6, C7; Lothian 1616, 1739; Must 95.

PLANTAGINACEAE

°*Plantago varia* R.Br. A small annual herb. Chippendale 2821; Lothian 10 numbers; Boyland 269; ACB.27842, 27901, 27921.

RUBIACEAE

°*Oldenlandia pterospora* (F. Muell.) F. Muell. A small, erect, twiggy herb or short-lived perennial, locally common on deep sand. Symon 4344.

°*Pomax umbellata* (Sol. et Gaertn.) Miq. A small undershrub. Lothian 1678.

Synaptantha tillaeacea (F. Muell.) Hook. f. A small slender annual. Lothian 1563, 1852; ACB.27942.

CUCURBITACEAE

Citrullus colocynthis (L.) Schrad. An alien perennial with a massive root system and herbaceous stems sprawling widely. Chippendale 4929.

Melothria maderaspatana (L.) Cogn. A scrambling vine, probably annual. Crocker C3; Must 87; ACB.27854.

CAMPANULACEAE

°*Lobelia heterophylla* Labill. Nov.Holl.Pl. 1.52.t.74. Locally common on interdune flats, the flowers are an attractive sky blue and the plants almost leafless at flowering. Chippendale 3953; Symon 4336.

Wahlenbergia gracilenta Lothian. An erect slender annual. Lothian 1538, 1539.

Wahlenbergia sieberi A.DC. A graceful herbaceous perennial. ACB.27946.

BRUNONIACEAE

°*Brunonia australis* Sm. An attractive annual or short-lived perennial herb, locally common on the flats. Crocker C5; Symon 4343.

GOODENIACEAE

°*Calogyne berardiana* (Gaudich.) F. Muell. An annual herb from hard stony flats. Crocker C2, C5; Lothian 1430, 1567, 1861, 1886; Must 63.

Goodenia argentea J. M. Black. A weak sprawling herb. Lothian 1535, 1834, 1853.

°*Goodenia cycloptera* R.Br. A sprawling annual or short-lived perennial herb. Locally very common on flats and upper slopes. Crocker C6; Lothian 8 numbers; Symon 4353; Must 109.

Goodenia glabra R.Br. An herbaceous perennial Must 61.

Goodenia heterochila F. Muell. A small sprawling perennial herb from the upper slope or dune crest. Winkworth 629; Forde 1285.

Goodenia lunata J. M. Black. A sprawling, colonial, herbaceous perennial. ACB.27789, 28028.

°*Goodenia mitchellii* Benth. A perennial herb collected from interdune flats. Chippendale 1601; Boyland 274; Must 328; ACB.27867.

°*Goodenia subintegra* F. Muell. ex Tate. A small perennial herb from sandy clay interdune flats. Boyland 305.

°*Lechenaultia divaricata* F. Muell. A small shrub forming rigid, intricate, rounded bushes on deep sands in interdune slopes. Crocker; Lothian 1603; Boyland 315; Symon 4381, 4349; ACB.27873.

°*Scaevola collaris* F. Muell. An undershrub from sandy clay at edge of a salt lake. Crocker C20; Boyland 231.

°*Scaevola depauperata* R.Br. Another rigid intricate small perennial from deep sands on the long slope of the dunes. Crocker C5, C8, C18; Lothian 1674, 1685; Symon 4380, 4352; Must 68.

°*Scaevola aemula* R.Br. A small spreading annual or perennial from depressions. Winkworth 670; Must 119.

°*Scaevola ovalifolia* R.Br. An erect undershrub. Crocker C3, C20; Chippendale 4935; Lothian 1481, 1781, 1875; Boyland 272.

°*Velleia connata* F. Muell. An erect annual, scattered plants from deep sand. Symon 4335.

ASTERACEAE (COMPOSITAE)

°*Angianthus pusillus* (Benth.) Benth. A small ephemeral herb. Lothian 1415, 1474, 1597, 1692, 1746, 1823; ACB.27937

°*Brachyscome iberidifolia* Benth. An annual herb. Lothian 1434, 1754, 1795, 1822.

°*Calotis erinacea* Steetz. A tough, herbaceous perennial from the upper slopes of the dunes. Crocker C7; Lothian 1620, 1668, 1741; Symon 4340; Must 71; ACB.27843A, 28036.

°*Calotis hispidula* (F. Muell.) F. Muell. A small ephemeral on the interdune flats. Lothian 1547, 1854; Symon 4402; ACB.27782, 27890, 27966.

°*Calotis multicaulis* (Turcz.) Druce. An annual herb on clayey sandy soils on interdune flats. Lothian 1530, 1560, 1897; Boyland 296; ACB.27832, 28000.

Calocephalus knappii (F. Muell.) Ewart & White. An erect annual on swale flats. Must 74, 318.

Calocephalus platycephalus (F. Muell.) (Benth). A small annual. Chippendale 6574.

Centipeda cunninghamii (DC) A.Br. et Aschers. A small annual or perennial herb. ACB.27953.

Centipeda thespidioides F. Muell. A small prostrate herb often on flooded sites. Lothian 1541 1577; ACB.27841, 27994.

°*Craspedia chrysantha* (Schlechtd) Benth. A small annual, occasional patches on the flats. ?Winkworth 660; Symon 4361.

°*Gnephosis eriocarpa* (F. Muell.) Benth. A small annual. Chippendale 2839, 6592; Lothian 1426, 1550, 1841; Boyland 272A; ACB.27785, 27836.

Gnephosis foliata (Sond.) Eichler. A small annual herb. Chippendale 2849. 3952, 6593; Lothian 1553, 1870; ACB.27797, 28023.

°*Gnephosis skirrophora* (Sond. et F. Muell.) Benth. A small annual herb. Boyland 236A.

°*Helichrysum ambiguum* var. *paucisetum* J. M. Black. A perennial herb. Crocker C13; Lothian 1450, 1602, 1675, 1740.

Helichrysum cassinianum Gaudich. An erect annual. Winkworth 666; Must 64; ACB.27851.

°*Helichrysum davenportii* F. Muell. An erect annual. Crocker (as *H. roseum* var.) C8; Must 62.

Helichrysum lindleyi Eichler. An erect annual. ACB.28027.

Helichrysum semifertile F. Muell. A small annual on clayey sandy soil on interdune flats. Boyland 294; ACB.28025.

°*Helipterum floribundum* DC. A small annual at times very abundant on interdune flats. Crocker C2; Winkworth 643; Chippendale 1611, 6575; Lothian 1425, 1520, 1585, 1625, 1770, 1846, 1869; Boyland 268; ACB.27900, 28026.

Helipterum charsleyae F. Muell. An erect annual. Crocker C4-C5; Winkworth 662; Must 70; ACB.27988.

Helipterum microglossum (F. Muell. ex Benth.) Maiden and Betche. A small sprawling annual. Lothian 1836, 1898.

°*Helipterum moschatum* (A. Cunn. ex DC.) Benth. An erect annual. Crocker C4, C8; Lothian 1437, 1480, 1584, 1609, 1635, 1679, 1737, 1763, 1766, 1791. 1881; Boyland 261; Must 316; ACB.27755, 27934.

Helipterum pterochaetum (F. Muell.) Benth. A perennial herb. Crocker C4; Chippendale 1648, 6598; Must 111.

Helipterum stipitatum (F. Muell.) F. Muell. ex Benth. Crocker C4-C5; Winkworth 665; Must 89.

Helipterum strictum (Lindl.) Benth. A small annual. Chippendale 1638; Lothian 1529, 1545, 1586.

°*Helipterum tietkensii* F. Muell. An erect annual, scattered plants on the flats. Chippendale 2840; Symon 4334.

Ixiolaena leptolepis (DC) Benth. A small annual. Chippendale 1538; Lothian 1529, 1545, 1586.

Ixiolaena tomentosa Sond. & F. Muell. ex Sond. A perennial herb. ACB.27907.

Millotia greevesii F. Muell. A small annual. Boyland 267.

Minuria denticulata (DC.) Benth. A small perennial. Chippendale 2835; ACB.27887, 27927, 27949, 27987.

Minuria leptophylla DC. A small undershrub. Chippendale 2844; Must 78, 319.

**Myriocephalus stuartii* (F. Muell. and Sond. ex Sond.) Benth. An annual, very common and widely spread in almost all sites except the mobile dune crests, repeatedly collected. Winkworth 651; Chippendale 1598, 2838, 6576; Lothian 1495, 1579, 1611, 1669, 1728, 1756, 1768, 1784, 1879; Boyland 273; Symon 4338; Must 72; ACB.27761, 27844.

**Podocoma nana* Ewart & White. A small prostrate annual. Lothian 1623.

**Podolepis canescens* A. Cunn. ex DC. An erect annual, occasional plants on the flats. Lothian 1423, 1703, 1894; Symon 4333.

Podolepis capillaris (Steetz) Diels. A slender erect annual. ACB.27932, 27983.

Pterigeron dentatifolius F. Muell. A small annual. Lothian 1515, 1590.

Pterigeron liatroides (Turcz.) Benth. An erect rigid perennial herb. ACB. 28021.

Pterocaulon sphacelatum (Labill.) Benth. & Hook. A stiff erect undershrub. Chippendale 1631, 4934.

Rutidosis helichrysoides DC. An erect perennial. Chippendale 4939; Lothian 1552; Must 340; ACB.27986.

**Senecio gregorii* F. Muell. An erect annual, common on flats and slopes, widely collected. Crocker C3, C4; Winkworth 644; Chippendale 1597, 2837; Boyland 275; Must 66; ACB.27760.

**Senecio lautus* Sol. An annual or short-lived perennial herb. Crocker C20; Symon 4339; Lothian 1436, 1482, 1566, 1608, 1632, 1689, 1758, 1769, 1785, 1878.

**Waitzia citrina* (Benth.) Steetz. in Lehm. Pl. Preiss 1, 454. An erect annual locally plentiful on the flats. Symon 4403.

APPENDIX

Plants from the Upper Slopes or Dune Crests

Poaceae
Plagiosetum refractum
Eriachne aristidea
Zygochloa paradoxa

Chenopodiaceae
Rhagodia spinescens var. *deltophylla*
Salsola kali

Amarantaceae
Ptilotus latifolius
Ptilotus polystachys

Aizoaceae
Trianthema pilosa

Portulacaceae
Calandrinia spp.
Portulacca intraterranea

Brassicaceae
Blennodia pterosperma

Mimosaceae
Acacia ligulata
Acacia dictyophleba

Caesalpiniaceae
Cassia pleurocarpa

Fabaceae
Crotalaria cunninghamii
Crotalaria dissitiflora
Psoralea eriantha
Swainsona rigida
Tephrosia purpurea

Zygophyllaceae
Tribulus hystrix

Euphorbiaceae
Euphorbia wheeleri

Boraginaceae
Trichodesma zeylanicum

Goodeniaceae
Goodenia cycloptera

Asteraceae
Calotis erinacea
Myriocephalus stuartii

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STRATIGRAPHY AND LANDSCAPE RELATIONS OF SOIL MATERIALS NEAR ADELAIDE, SOUTH AUSTRALIA

BY *J. B. FIRMAN*

Summary

In the paper, the superposition, emplacement and organization of soil materials through time is the central theme. Tectonic and geological events are outlined as a necessary pre-requisite to the stratigraphic study of materials in soil profiles. Soils in the Adelaide area are defined and materials in soil profiles are identified. Stratigraphic analysis is employed to bring out time of origin of various layers. Finally , soil-landscape relations are set down and the history of soil development is briefly described.

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[Read 8 May 1969]

SUMMARY

In this paper, the superposition, emplacement and organisation of soil materials through time is the central theme. Tectonic and geological events are outlined as a necessary pre-requisite to the stratigraphic study of materials in soil profiles. Soils in the Adelaide area are defined and materials in soil profiles are identified. Stratigraphic analysis is employed to bring out the time of origin of various layers. Finally, soil-landscape relations are set down and the history of soil development is briefly described.

INTRODUCTION

Soil investigations have been carried out by the South Australian Geological Survey over the past fifteen years. This work had its origins in a study of the soils and geology of Adelaide (Aitchison, Sprigg and Cochrane, 1954) which was designed to assist engineers and architects concerned with foundations of small buildings. The investigations were later extended to provide basic information for most kinds of soft ground engineering. In 1964, a statewide stratigraphic study of superficial deposits was undertaken by the writer (Firman, 1967 pp. 165-180, 1968 pp. 569-576, and 1969 pp. 204-233). Materials on the western side of the area dealt with herein were formally described in Firman, 1963 and 1966, and the various stratigraphic units were later mapped throughout the Adelaide 4-mile sheet (Thomson, 1969). The references mentioned provide background for this paper.

In 1968, stratigraphic investigations were made near Adelaide to provide information on soil genesis, particularly of the deeper substrates, during mapping of the Gilles Plains-Modbury-Tea Tree Gully area by Soil Consultant J. K. Taylor and Engineering Geologist B. D. Steel (Steel and Taylor, 1968). The study was extended outside the detail map area so as to transect the trend of rocks, landforms and soils on the margin of the Great Australian Rift, and to link continental deposits and marine deposits on the western side of the transect area (Plate 1 and Fig. 1).

The stratigraphic approach to the study of soils begins with the description and delineation of materials in the field, leads to definition of some of the factors controlling soil formation through time, and concludes with the history of soil development. In this paper, some of the conclusions about soil and soil development are unconventional, mainly because the stratigraphic approach restricts interpretation of the various soil features to those compatible with stratigraphic principles.

The study begins with an examination of tectonics and geological events. This is not only background material, but is a necessary part of the study; without it, later statements on soil evolution in the section on soil-landscape relations cannot be fully understood. The reader will see in the sections on soils in the Adelaide area that materials in soil profiles are examined from both a "geological"

[1] Published with the approval of the Director, S.A. Department of Mines.

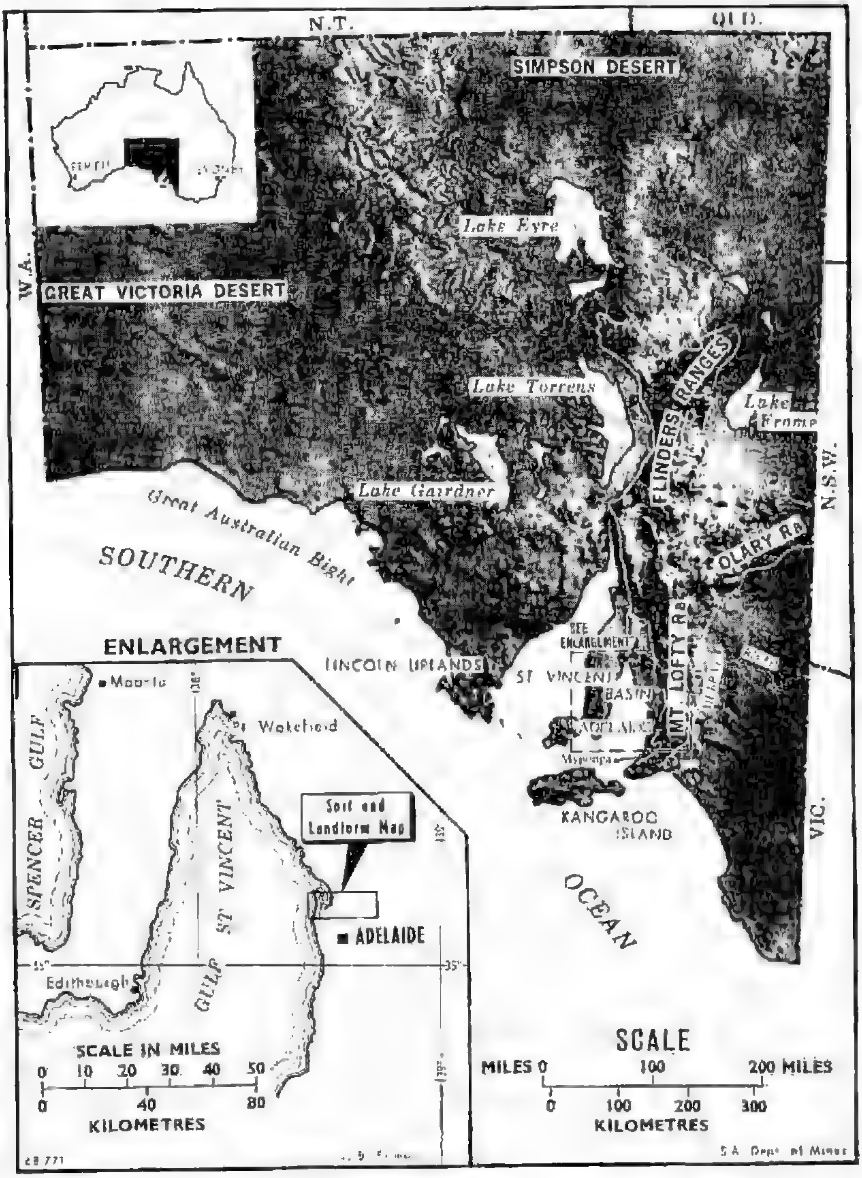

PLATE 1
Morphological map of S.A. showing localities and detailed soil transect near Adelaide.

and "pedological" point of view. The result is that the soil is examined layer by layer (the individual layers being traced through different soils and landscapes), and, also, as complete assemblages of layers naturally occurring in associated landscapes. It is important to remember that the materials so described have all been previously recorded using conventional soil terminology in many hundreds of soil profiles throughout the metropolitan area.

Some of the materials described in shallow soil profiles as A and B horizons, also occur as substrates and buried deep in sedimentary sequences. In order to

trace out the layers and establish their stratigraphic position, it has been necessary to sample to much greater depths than is normal during soil survey.

Although conventional soil terminology has been employed herein, the reader will appreciate that the simple and conventional view of soil and soil formation is not taken as a model. Rather, it is hoped that a more generally useful and widely acceptable definition of the soil will eventually result from this kind of study.

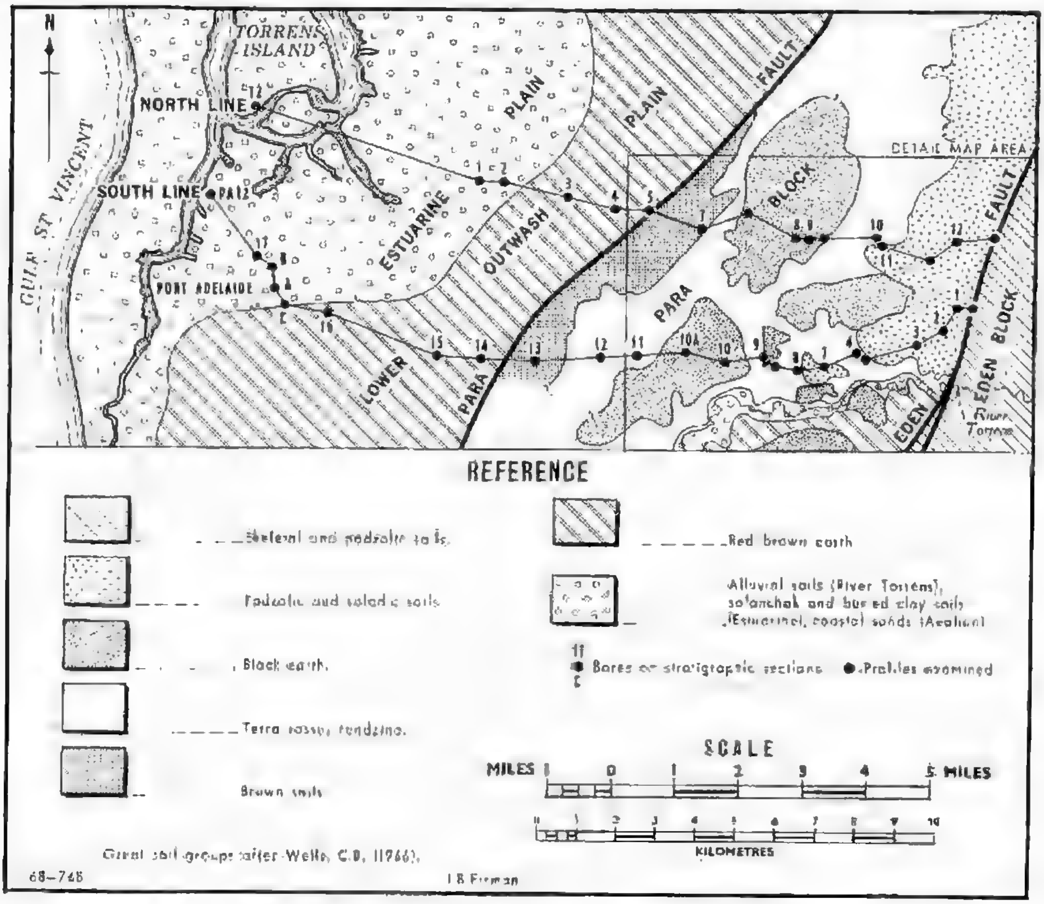

Fig. 1. Soil and landform map, Adelaide Area.

THE TECTONIC FRAMEWORK AND GEOLOGICAL EVENTS

Fault blocks occupy the eastern or Mt. Lofty Ranges portion of the area, and the Great Australian Rift occupies the western portion below the Lower Outwash and Estuarine Plains. Near-vertical faults control the broader features of landform and soil distribution. Although older surfaces provide evidence for continued elevation of the ranges from Permian time onward, the formation of major features in the modern landscape began with disruption of the mid-Tertiary land surface by block-faulting and tilting during the Kosciuskan Orogeny. Movements continued into the Pleistocene and the area is at present within the Australian region most subject to seismic disturbances (Bolt, B. A., 1957; Kerr-Grant, Colin, 1956; and Sutton, D. J. and White, R. E., 1968). Remnants of the dismembered

pre-Tertiary surface came to lie at elevations separated by as much as 4,000 feet. Sediments of the St. Vincent Basin—now within St. Vincent's Graben and a part of the Great Australian Rift—and Myponga Basin—now within the Mt. Lofty Ranges—were once contiguous, but are now separated vertically by no less than 1,000 feet. Local changes in elevation ranging from a few feet to about 400 feet can be demonstrated by tracing late Pliocene marine sediments across the Para Fault. The Keswick Clay, one of the youngest layers in the sequence of Pleistocene clays, is found on both sides of the Eden Fault: It occurs at an elevation of about 150 feet above sea-level near Adelaide on the Para Block, and about 600 feet above sea-level on an up-lifted sub-horizontal surface cut across the tilted Eden Block.

In St. Vincent's Graben, beneath the Estuarine Plain (Fig. 1), a 300 to 400 feet thick sequence of clays and sandy clays with sand and gravel lenses, the Hindmarsh Clay, records strong alluviation in the Lower Pleistocene.[1] The alluvial plain at this time extended far beyond the modern coast. The Hindmarsh Clay also occurs on the Para Block, where it is overlain by the Keswick Clay, a somewhat younger unit occurring as a thin discontinuous fluviatile deposit. Middle Pleistocene faulting post-Hindmarsh Clay and pre-Glanville Formation displaced the Hindmarsh Clay across the Para Fault (see Fig. 2, North Line). This faulting may have occurred at the same time as the faulting which displaced the Keswick Clay across the Eden Fault to the south.

Above the Hindmarsh Clay are remnants of various deposits, including calcreted loess and, on the seaward margin, shallow marine Glanville Formation. These deposits record fluctuations in sea-level, aeolian deposition, soil formation, faulting, and extensive subaerial erosion during the Middle Pleistocene. C^{14} dating of shell from the Glanville Formation suggests that the unit has an age in excess of 45,000 years B.P. (See Fig. 2, North Line, Bore T2 at the west end.)

Later faulting and renewed alluviation during the Upper Pleistocene is recorded by Pooraka Formation. At the time, the alluvial plain extended out into Gulf St. Vincent following a withdrawal of the sea at the end of the Middle Pleistocene. N. B. Tindale, when discussing the advent of man in Australia, referred to St. Vincent Gulf as "... a great alluvial plain, extending down towards Kangaroo Island." (Symposium on Geochronology and Land Surfaces in Relation to Soils in Australia 1961—unpublished.) Layers of vermiform carbonate nodules at the top of this formation and younger carbonate patches and nodules formed during aeolian re-working of Pooraka Formation, are assigned to the Loveday Soil. Thin deposits of red clay without carbonates mark the top of the unit.

Recent marine gulf, estuarine, littoral and aeolian sediments overlie the seaward margin of the Pooraka Formation and record the rise of the Flandrian Sea. Two of the most prominent units are Lipson Formation and St. Kilda Formation. C^{14} age determinations carried out by Scripps Institution of Oceanography in 1967-68 on shell from St. Kilda Formation north of the transect area near Sandy Point, range from 3,800 $\pm$ 500 years B.P. for shell from the base of the unit to 1,120 $\pm$ 75 years B.P. for shell from stranded beach ridges at the top of the unit. Aeolian deposition during the Recent is marked by the reddish brown Fulham Sand of the older dunes on the Estuarine Plain south of Port Adelaide, and the Semaphore Sand of the dunes fringing the modern coast.

SOILS IN THE ADELAIDE AREA

This part of the paper is based upon the stratigraphic sections shown on Figures 1 and 2. The sections extend east-west through the transect area for a

[1] Detailed subdivisions of Pleistocene time are shown on the Correlation Chart (Fig. 3).

distance of about 15 miles. The profiles are about 12 feet deep. On the sections, datum is ground surface and correlation is made between adjoining bores. The observation points are so closely spaced that correlation lines approximate the real distribution of units between bores. Bores in the eastern part of the transect area are shown on the map accompanying a report by Steel and Taylor (1968). Copies of bore logs are available on request at the S.A. Department of Mines.

The soils have been described in some detail by various workers whose papers have been summarized by Wells (1966). A version of Wells' map with modifications, including details derived from the map by Steel and Taylor, is shown on Fig. 1. The original work of Aitchison, Sprigg and Cochrane (1954) is particularly relevant elsewhere in the transect area. Their usage of great soil group nomenclature and of symbols for the groups has been followed in this paper. The symbols are used to designate important soil types on the stratigraphic sections (Fig. 2) and on the Correlation Chart (Fig. 3). Further description and classification of the soils is given in Stephens (1962) and Northcote (1960).

Description of Soil Groups

The great soil groups commonly occurring are set out below, together with representative profiles where appropriate:

Skeletal Soils (SK): Shallow soils which contain abundant coarse rock fragments derived from the underlying Tertiary sandstone or the sandstone, shale, dolomite and siltstone of the Proterozoic Burra Group. The soils are without profile form.

Podzolic Soils: Soils with sandy upper horizons, over yellow clay B horizons (YP), or red clay B horizons (RP), or deep sandy subsoil (P), or ferricrete pan with older mottled zones.

PROFILE 1

Podzolic Soil. S1 on Fig. 2 (Bore No. 754728052). Vista Estate J/6. Section 5626, Hd. Yatala

Age	Unit	Horizon	Depth in feet	Description
RECENT		A1	0 – 5″	Yellowish brown (10YR5/4) sand. Lower boundary sharply defined by colour change and presence of gravel lower.
		A2	5″ – 1′ 2″	Reddish yellow (7·5YR7/6) fine sand with scattered ferruginous gravel.
PLEISTO-CENE	Altered Tertiary Sand	Bs	1′ 2″ – 3′ 8″	Yellowish brown (10YR5/6) mottled with red (10R4/6) sandy clay, changing to clayey sand at about 2 feet.
TERTIARY		C	3′ 8″ – 4′ 2″	White fine—medium grained quartz sand with red (10R4/6) mottles.

Remarks: Thin clay layer from 1′ 2″ to 3′ 8″.
Hard sand prevented deeper penetration.

Solodic Soils (S): Deep sandy surface layers over mottled clay subsoil. A hard-setting sandy clay occurs at the top of the subsoil in some places.

PROFILE 2

Solodic Soil. Between Sand Quarry section and N12 on the North Line of Fig. 2

Age	Unit	Horizon	Depth in feet	Description
RECENT	Thin slope deposits showing bleaching at the base	A1	0 – 10″	Light brown (10YR7/3) silty fine sand with some grey organic material between 2 in. and 6 in.
		A2	10″ – 1′ 7″	Pale brown (2·5Y8/2) silty fine sand becoming paler towards the base.
PLEISTOCENE	Keswick clay equivalent	B	1′ 7″ – 3′ 2″	Light yellow brown (10YR6/4) fine sandy clay with fine dark red (10R3/6) mottles. Prismatic structure.

Remarks: The B horizon in this soil is altered Tertiary sand showing structure and mottling.

Black Earths (BE): Fine textured grey and black soils with variable profile characteristics. Strong cracking and gilgai are common. Material derived from the black earth and transported downslope produces storeyed soils with black earth affinities.

PROFILE 3

Black earth. N10 on Fig. 2 (728156501) Modbury—Nth. Adelaide, Pl. No. 11, Section 1565, Hd. Yatala

Age	Unit		Horizon	Depth in feet	Description
PLEISTOCENE	Thin clay layer		A	0 – 10″	Very dark grey and olive (5Y4/3) vaguely mottled clay. Strong effervescence. Lower boundary well defined by colour change and patches of lime below.
	Keswick Clay	Older carbonate	B	10″ – 1′ 8″	Light yellowish brown (10YR6/4) slightly silty clay with white patches of earthy lime (2·5Y8/0). Strong effervescence. Lower boundary gradational.
				1′ 8″ – 6′ 1″	Light yellowish brown (10YR6/4) somewhat silty clay. Strong effervescence.

Terra Rossa and Rendzina (TR and RZ): Reddish brown or dark brown topsoils overlie very calcareous zones in weathered calcareous bedrock or loess with or without a calcrete pan.

Brown Soil. Also called Mallee Soil or Brown Solonized Soil (BS): Soils with shallow loamy or clayey surface horizons over very calcareous zones, normally mixtures of carbonate silt and sand. Calcrete pan, rubbly or nodular carbonate is common. Mottled clay or rock occurs at the base of the profile in some places.

PROFILE 4

Terra Rossa. Between N7 and Lincoln Court section on Fig. 2
Transitional between brown soil and red-brown earth

Age	Unit	Horizon	Depth in feet	Description
RECENT		A1	0 – 3″	Light yellowish brown (5YR4/4) silty fine grained sand.
PLEISTOCENE		A2	3″ – 1′ 3″	Dark brown (5YR8/4) fine sand becoming reddish brown and somewhat clayey lower.
			1′ 3″ – 1′ 9″	Rubbly off-white (10YR8/3) calcrete.
			1′ 9″ – 3′ 6″	Weakly cemented off-white (10YR8/3) calcareous earth.

Remarks: The reddish brown part of the A2 horizon can be traced into adjoining profiles where it is separately identified as the "thin clay layer" and forms a B horizon in the red brown earth Type RB4.

The calcrete is a younger calcrete layer in Bakara Soil (Firman, 1967).

PROFILE 5

Brown soil: Near S13 on Fig. 2 (Bore No. 752728040) Clearview-Folland Park Reserve J/4. Section 340, Hd. Yatala

Age	Unit	Horizon	Depth in feet	Description
			0 – 3″	Fill
RECENT		A	3″ – 1′ 3″	Yellowish brown (10YR5/4) silty fine sand. Strong effervescence. Lower boundary gradational with weak contrast.
PLEISTOCENE	Pooraka Formation Loveday Soil carbonate extends down to 8 ft. 6 in.	B	1′ 3″ – 3′ 3″	Very pale brown (10YR8/4) silty fine sand with soft irregular carbonate nodules and some nodules of Ripon Calcrete with later concretionary layers. Strong effervescence.
			3′ 3″ – 6′ 6″	Reddish yellow (5YR6/6) silty fine sand with abundant small hard lumps of carbonate. Strong effervescence. Lower boundary gradational but fairly well defined by moderate colour contrast.
	Hindmarsh Clay lime impregnated	B—C	6′ 6″ – 9′ 6″	Yellowish red (5YR5/8) clayey silty fine sand with clay content increasing downwards. Patches of earthy lime (10YR8/4). Strong effervescence. Lower boundary fairly sharp with strong texture contrast.
	Hindmarsh Clay	C	9′ 6″ – 13′ 6″	Dark red (2·5YR3/6) clay with a prismatic structure and angular blocky sub-structure. Moderate sheen on faces of structural units. A few pale grey and yellow patches occur. No effervescence.

Remarks: Interval 1 ft. 3 in. to 3 ft. 3 in. is possibly re-worked Loveday Soil (Firman, 1967).

Red Brown Earth (RB3, 4, 5, 6, 7 and 8): Soils with a loamy or sandy surface horizon overlying clearly marked red-brown clay subsoil. A calcareous horizon is present below the upper red-brown clay.

PROFILE 6 Fig. 8

Red brown earth. N3 on Fig. 2 (728009716). The Levels North Adelaide Pl. No. 11. Section Pt. 97, Hd. Yatala

Age	Unit	Horizon	Depth in feet	Description
RECENT	Re-worked Fulham Sand	A1	0 – 1′ 3″	Dark reddish brown (2·5YR3/4) fine sand. Lower boundary gradational and poorly defined.
PLEISTOCENE	Thin clay layer	A2	1′ 3″ – 1′ 10″	Reddish brown (5YR4/4) fine clayey and silty sand. Lower boundary gradational, but well defined by carbonate lower.
	Pooraka Formation	B1	1′ 10″ – 3′ 3″	Reddish brown clayey sandy silt (5YR4/4) with patches of reddish yellow (7·5YR8/6) earthy lime. Strong effervescence. Lower boundary gradational, but well defined.
		B2	3′ 3″ – 4′ 5″	Dark red (10R3/4) silty and fine sandy clay with a fine granular structure (angular blocky). Weak effervescence. Lower boundary gradational, but well defined.
		C	4′ 5″ – 7′ 0″	Red sandy and silty clay. Weak effervescence.

Alluvial Soils (AL): Soils with variable depth, sequence and composition, ranging from clayey silts to coarse gravel.

PROFILE 7

Alluvial soil. Upper Dry Creek Section on Fig. 2

Age	Unit	Horizon	Depth in feet	Description
RECENT	River alluvium		0 – 1′ 2″	Pale brown fine grained quartz sand.
			1′ 2″ – 2′ 6″	Light brown and yellow brown weakly structured clayey quartz sand.
PLEISTOCENE	Pooraka Formation	B	2′ 6″ – 3′ 6″	Light reddish brown clayey and silty fine grained quartz sand and sandy clay with scattered hard irregular vermiform carbonate nodules from 2 ft. 6 in. to 3 ft. 6 in. Manganese coatings on peds at 5 feet.
		C	3′ 6″ – 10′ 0″	
PROTEROZOIC	Burra Group		10′ 0″ – 10′ 6″	Quartzite.

Remarks: Loveday Soil carbonate from 2 ft. 6 in. to 3 ft. 6 in.

Solonchak (So): Saline estuarine or shallow marine sediments and associated buried red earths.

PROFILE 8

Solonchak. N2 on Fig. 2 (593102002). Cavan—Nth. Adelaide Plains. No. 10. Section 1020, Hd. Pt. Adelaide

Age	Unit	Horizon	Depth in feet	Description
RECENT	St. Kilda Formation		0 — 7″	Light greyish brown (10YR3/2) silty clay with very poorly developed vertical structure. Lower boundary gradational, but well defined.
			7″ – 1′ 4″	Light greenish brown silty clay. Weak effervescence. Lower boundary gradational and not well defined.
PLEISTOCENE	Pooraka Formation	A B—C C	1′ 4″ – 3′ 0″ 3′ 0″ – 5′ 0″ 5′ 0″ – 6′ 6″	Pale reddish brown (7·5YR6/6) silty clay with irregular reddish brown patches of earthy lime between 3 and 5 feet. Strong effervescence. A few carbonate granules and angular quartz pebbles are scattered throughout. Lower boundary not well defined.
			6′ 6″ – 8′ 0″	Light yellow clay without shell, transitional to Glanville Formation below 8 ft.
	Glanville Formation		8′ 0″ – 10′ 10″	Light yellow brown shelly clay.
	Hindmarsh Clay		10′ 10″ – 11′ 10″	Light brown, red mottled clay.

Remarks: Loveday Soil carbonate between 3 ft. and 5 ft.

Coastal Sands (DS1, DS2): Fossil fragment or quartz sand, mainly in dunes, with minor accumulations of organic material in the surface horizons.

PROFILE 9

Coastal sand. Bore through dune near S17 and S17b, Fig. 2 (593113501)
North Adelaide Pl., No. 10, Section 1135, Hd. Pt. Adelaide

Age	Unit	Depth in feet	Description
RECENT	Semaphore Sand	0 – 2′ 6″	Yellowish brown fine-grained sand. Surface 2 in. stained greyish brown with organic matter.
		2′ 6″ – 6′ 0″	Pale yellow fine-grained quartz sand. Weakly cemented zone from 4 ft. 6 in. to 5 ft. 0 in.
	St. Kilda Formation	6′ 0″ – 7′ 6″	Dark yellow weakly cemented fine-grained quartz sand.
		7′ 6″ – 9′ 6″	Yellow fine-grained quartz sand.

Remarks: Adjoining swamps below level of dune contain light bluish grey sand of St. Kilda Formation, with a thin veneer of grey and yellow finely mottled soft clay.

Materials in Soil Profiles

In this paper emphasis is on the complete soil profile rather than the "solum", or upper part of the soil. Unaltered parent materials forming part of the profiles are of various kinds and include Proterozoic sediments; Tertiary sand, and various zones in the laterite profile; the Hindmarsh Clay, Keswick Clay and loess and associated deposits; and the thin clay layer, the sandy slope deposits on the valley walls and the younger materials of the estuarine plan. The parent materials have been extensively modified by later soil-forming processes and, in their altered condition, occur as soil horizons throughout the area. (See Fig. 2.) Arranged in order from oldest to youngest, the various materials recorded in descriptions of soil profiles (including unaltered parent material) are ancient weathered zones in Proterozoic bedrock (not shown separately on the sections); ferricreted layers; silicified layers, and older mottled zones in Tertiary sand; mottled Hindmarsh Clay; Keswick Clay; structured Keswick Clay and structured clay zones in older Tertiary sand and weathered Proterozoic siltstones marginal and stratigraphically equivalent to Keswick Clay; pink silt with relic rock structure; loess-quartz sand and loess—older clay mixtures; older carbonates in pink silt and older units, including Keswick Clay, Hindmarsh Clay, Tertiary sand and Proterozoic bedrock; calcrete; Pooraka Formation; Loveday Soil carbonate in Pooraka Formation and Tertiary sand; the upper thin clay layer; and A horizons and other near-surface horizons in solonchaks.

Soil Horizons and Nomenclature

During logging of soil profiles, A horizons were taken to be surface horizons, usually with an accumulation of organic material, where eluviation is important; B horizons were taken to be transitional horizons, including clay layers, wherein accumulation and illuviation may occur; C horizons were logged where material little influenced by organisms and showing evidence of weathering occurred below A or B horizons; D horizons were taken to mean relatively unweathered material. This is close to the early Russian usage, wherein the soil profile is dominated by A and O horizons which reflect the proximity of ground surface, and by C horizons showing little evidence of soil formation.

The A, B, C system derives from the examination of soil profiles, so that diagnostic characters are matters of observation and the system is usable irrespective of differing theories of soil genesis. Its application to soil horizons in the transect area is now developed. The lowermost layers, represented on the Correlation Chart (Fig. 3) by katamorphosed basement rock and Tertiary sand, are the C and D horizons of earlier literature, and the R horizon of I.S.S.S. (1967). These horizons are generally described as weathering and oxic horizons. Above the katamorphosed basement rock and Tertiary Sand are pan-like B horizons including silcrete and ferricrete with mottled clayey B2 horizons. These are normally described as "fossil" lateritic podzols and derivatives with the original A horizon missing.

Weathered and diagenetically modified layers of various origins extend on the Correlation Chart from the Hindmarsh Clay up to the thin clay layer. The presence of clay layers and horizons of carbonate accumulation is characteristic. Provided that these layers are not obviously sedimentary, they are described as B horizons in conventional studies. Where some of the sedimentary layers are recognised, the soil is described as storeyed and a more sophisticated number terminology is used.[1] The middle layers can be subdivided into two: At the top are salic horizons which are simply younger poorly differentiated materials of the

[1] An early example of this usage is in Ruhe. R. V., and Daniels, R. B. (1958). Later comment is given in I.S.S.S. (1967, p. 5).

coastal margin and inland depressions, or older materials saturated by saline solutions. Stratigraphically below are the horizons usually termed illuvial, the B and BV horizons of I.S.S.S. (1967) and calcrete pans. These lower layers can be designated according to SCS (1960, pp. 35-65) from top to bottom as follows: Argillic horizons of the thin clay layer; argillic horizons of the Pooraka Formation with manganese coating on the peds; calcic horizons of the Loveday Soil, Bakara Soil, loess and carbonate silt-quartz sand mixtures; argillic and natric horizons of the older solonized clay layers; and argillic horizons with manganese coatings and gypsic horizons.

The uppermost layers indicated on the correlation diagram are the A and O horizons of I.S.S.S. (1967). The A horizons of degraded soils are included also, and there is a general correspondence to the epipedons and albec horizons of SCS (1960). In the older literature these layers are described as eluvial horizons, or horizons of organic material accumulation. The youngest sedimentary layers in soil profiles are included here also.

Stratigraphic Analysis

Soil stratigraphy begins with the description of horizons according to differences in colour, structure, texture, composition, consistence and such things as the presence or absence of carbonates. The same criteria are used, as far as possible, for horizons within and below the zone of seasonal moisture variation, so as to avoid an artificial contrast between near-surface horizons and those at depth. Decisions about genesis or any particular horizon, the classification of horizons into lithological and pedulogical categories, and the recognition of palaeosols are not made during description of horizons, except in the case of rock-weathered rock comparisons, which are made by examination of similar materials in different conditions, and as indicated by relic minerals and structures in weathered materials. Decisions about genesis are made after the layers have been placed in their proper stratigraphic sequence.

The stratigraphic approach yields the relative age of horizons. This information is supplemented by identification of remains of flora and fauna in intercalated horizons, and by absolute age determinations on shell, peat and other materials. (An example has been given previously on the western end of the stratigraphic sections. In that area, C^{14} dated shelly marine deposits aid in the reconstruction of pedological events.) With regard to relative age, widespread layers are traced throughout the landscape so that the position in sequence of these and other horizons is established: the thin clay layer is a through-going layer and occurs as an important horizon in podzolic soils, red-brown earths, terra rossas and brown soils. A colour variant of the same layer also appears in some black earths. The same layer is found in different positions within the soil profiles. For example, it occurs as an A horizon in the soil with terra rossa affinities in Bore N7 and as a B horizon in the red-brown earth in bore N5. (See Fig. 2.) The stratigraphic approach also yields other kinds of information: Both red-brown earths and podzolic soils are developed over Tertiary sand (N11 and N12 of Fig. 2). Black earths with a deep layer of reactive clay are formed only over thick Keswick Clay, similar soils with less reactive profiles occur in lateral equivalents of the Keswick Clay developed in adjoining Tertiary sand and weathered bedrock. Black earths and rendzinas (BZ and BE) and red-brown earths and terra rossas (RB4-TR) commonly occur together on the Para Block. (See Fig. 2, North Line between N7 and Nelson Road.) The A horizons are texturally similar in each case. Red-brown earths are differentiated from terra rossas, and black earths from rendzinas mainly because of the presence in the terra rossa and rendzina profiles of calcareous older layers. Where calcrete is continuous

under sandy A horizons, terra rossa (red) or rendzina (brown and grey) are identified irrespective of lower layers. Where calcrete is thin and/or calcareous weathered bedrock occurs in red soil profiles containing the thin clay layer, red-brown earth is identified. The thin clay layer also occurs between the sandy A horizons and the calcrete or calcareous earth in some terra rossas and rendzinas, but where this layer is thick and well-developed the red soils are called red-brown earths and the grey soils, black earth.

On the stratigraphic sections, some horizons contain only one sort of material and others are a combination of layers of different materials. That is, layers occur separately, together or superimposed. "Layer" includes soil horizons, sedimentary layers, emplaced layers such as carbonate zones etc. and organized layers structured in characteristic ways. Only those layers necessary for proper identification of the soils are shown on Figs. 2 and 3. Structure layers and some emplaced layers are omitted. Because of this broad meaning of "layer" in stratigraphic analysis, layers naturally occurring as horizons in soil profiles are identified as such, particularly where the discussion concerns matters of ordinary pedological usage.

Stratigraphic analysis separates the various layers according to time of origin. This separation facilitates a close examination of layer relationships. For example, the youngest soil unit produced by chemical differentiation is the younger carbonate layer in Loveday Soil. (See Fig. 2 and Fig. 3, the Correlation Chart.) The youngest rock unit in which this carbonate is emplaced is the Pooraka Formation. That is, the Pooraka Formation was laid down first and the carbonate was emplaced shortly afterwards. It can be said that the carbonate is *stratigraphically associated* with Pooraka Formation. Because all the other units are older than Pooraka Formation, it follows that the younger carbonate is not genetically connected with them: It is not produced by processes responsible either for the formation of older parent materials or of soil layers associated stratigraphically with these materials. The same sort of argument applies to other layers in the profiles examined. Two important concepts follow: Firstly, because horizons in any one profile were formed in different ways at different times, the simple concept of profile differentiation from homogeneous material must be limited, possibly to the time of formation of individual layers. Secondly, because deposition precedes soil formation in succeeding stratigraphically associated layers, soil formation must be periodic.[1]

On the Correlation Chart, stratigraphic units are listed vertically according to time of formation, with the oldest at the base and the youngest at the top. The chart has assemblages representing real soil profiles arranged left to right with letters at the top indicating the great soil groups (P for podzolic; S for solodic etc.). The assemblages record all the layers known to occur in soil profiles at the type listed. Layers essential to the definition of the type are shown with a cross, others with a solid circle.

Where certain layers are commonly associated in more than one way within a given soil type, more than one assemblage is shown under the type symbol. The assemblages are arranged from left to right according to decreasing age of the lowermost layer in the assemblage essential to the definition of the type. Older soils that are "better differentiated" naturally appear on the left hand side of the chart. Because older soil layers have been stranded due to increasing uplift in the ranges, there is a trend left to right from the ranges down to coastal plan.

The various layers occurring in the soils reflect the environment prevailing during their formation. Horizontal lines on the Correlation Chart mark tectonic and climatic events that were followed by profound changes in the landscape.

[1] For a different approach yielding the same conclusion see Butler (1959)

These events produce the genetic groups of soils delineated on the chart by strong horizontal (and vertical) lines. The way in which these groups are formed and preserved, and the way in which they relate to the present zonal pattern will be discussed in a later paper.

SOIL-LANDSCAPE RELATIONS

Much of the history of landform development has already been dealt with in the appropriate sections on tectonics and geological events. Landforms in the area have been discussed by numerous authors, principally Fenner, Charles (1930, pp. 1-36) and Sprigg, R. C. (1945, pp. 313-347).

Most of the land-forms were developed following faulting and disruption of the pre-Tertiary surface. Periodic uplift of the Mt. Lofty Ranges has been followed by erosion and sedimentation. Uplift has outstripped stream incision, so that remnants of successively younger surfaces are found at successively lower elevations along the flanks of the ranges.

Shifts in Pleistocene sea-level have been of sufficient magnitude to change the rate and extent of fluvial processes, but high sea-levels have not affected land forms east of the Estuarine Plain.

Various landform-soil associations are now described and a brief history of soil development is given for each landform unit. Landform units, topography and associated soils are shown above the stratigraphic sections on Fig. 2. Soil types and their symbols are set out briefly at the beginning of the section on soils in the Adelaide area, on the Correlation Chart, Fig. 3. and in the following text. The arrangement of symbols on the topographic sections of Fig. 2 follows Steel and Taylor (1968). Dominant forms are shown in large print and soils of lesser importance in smaller print. Symbols for soils of roughly equal dominance are connected by a hyphen.

Eden Block

The Eden Block reaches heights up to 1,200 feet above sea-level. Monadnocks in the Mt. Lofty area south of the transect are up to about 2,400 ft. above sea-level, and stand sharply defined by the change in slope above the dissected remnants of the pre-Tertiary surface.

The western slopes of the block are steep due to strong dissection by streams of the Eden fault-line scarp. Remnants of older soil layers rest upon slopes which become increasingly steep with decreasing age of the layers: Ferricrete of the old laterite profile marks a gently undulating surface, slope deposits equivalent to pink silt and Pooraka Formation rest upon moderate slopes, younger thin red and yellow clay layers mark steep slopes. Modern slope deposits now lie upon the very steep slopes of valley walls adjusted to the modern drainage pattern.

The soils of the Eden Block are podzolic (P, YP, RP), and skeletal soils (SK). The symbols are used to represent these soils on Fig. 2 and the Correlation Chart, Fig. 3. In general, the podzolic soils are formed of young layers, including red and yellow clay, resting upon ferricrete and its derivatives or ancient weathering zones in bedrock. Minor occurrences of a red brown earth (RB1) occur outside the transect area on the lower slopes of the block where the red clay rests upon remnants of older carbonate horizons in katamorphosed bedrock. The skeletal soils are formed by erosion of older layers and the superposition on bedrock of younger layers adjusted to the steep slopes of the modern drainage pattern.

Para Block

The landform unit is bounded on the east by the Eden Fault and on the west by the Para Fault. The altitude of the block on the northern margin of the transect is about 700 feet above sea-level. The surface of the block declines to the south: On the southern margin of the transect it is about 250 feet above sea-level, and

south of Adelaide it stands at the same height as the adjoining coastal plain, that is about 100 feet above sea-level.

On the eastern margin of the Para Block, remnants of the ferricreted Tertiary surface occur, but these give way to the west to flat-lying surfaces developed prior to deposition of the Pleistocene Hindmarsh and Keswick clays, and finally, to the steeper slopes of the ancestral Pleistocene drainage patterns which now contain the modern streams.

After deposition of the Pleistocene clays and prior to strong incision, the Para Block received strong accessions of the aeolian lime. This material, and other carbonate from katamorphism of older rocks, was leached and calcrete pans were formed. Soils containing the characteristic calcrete pans are referred to the soil stratigraphic unit called Bakara Soil.

Dismemberment of the block by stream incision followed upon regression of the sea in which Glanville Formation was deposited.

Pooraka Formation was deposited in the valleys (see Upper Dry Creek section on the North Line of Fig. 2). Successively younger layers on increasingly steep slopes, including the thin clay layers formed at the end of Pleistocene time, Recent slope deposits and alluvium, and bed load of the modern stream channels are all contained within the ancestral Pleistocene drainage pattern.

The soils of the Para Block are podzolic (P) and solodic (S) soils, older red-brown earth, brown soil, black earth, terra rossa, rendzina and younger red-brown earth (RB8, BS, BE, TR, RZ and RB4 respectively, shown on Fig. 2 and the Correlation Chart, Fig. 3).

Prior to uplift and dissection the important soils were lateritic podsols on Tertiary sands. After dissection and later deposition of the Keswick Clay and the old red clay layer,[1] the important soils were solodic soils and the older red-brown earths (RB8). Then followed deposition of loess and development of calcrete pans characteristic of the brown soils. These soils were developed one after the other on flat-lying surfaces.

Following further uplift and deep dissection in the Upper Pleistocene, a complicated mosaic of soils appeared on the strongly undulating surface. Pooraka Formation appeared in the valleys and zones of nodular carbonate were later formed in this material. Further dissection was accompanied by formation of thin slope deposits of yellow, grey and red clay. These deposits form an essentially continuous layer, and reflect the adjacent source material from which they were derived: the yellow and red clays were superimposed on older layers in weathered bedrock and Tertiary sand to form podzolic soils; the grey clays were superimposed on older Keswick Clay and its equivalents (with or without parts of the calcrete and loess layers) to form black earth and rendzinas; the red clay was superimposed on thick calcrete and loess layers to form terra rossas, and upon the pink silt of weathered calcareous bedrock associated with calcrete to form the younger red-brown earths. Other red-brown earths in the Torrens River valley contain the younger red clay layer superimposed in some places on older clay layers revealed by dissection (RB3 and RB5).

Later, stream development and solifluction produced A horizons over soils on the slopes and the alluvial soils of the modern stream courses.

The Lower Outwash Plain

During Pooraka Formation time, the alluvial plain extended out into Gulf St. Vincent far beyond the limits of the modern coast. This followed a withdrawal of the Pleistocene sea at the end of the Middle Pleistocene.

[1] The old red clay layer occurs at the base of the red clay shown as Cr in bore S7 and S8 on the South Line.

Pooraka Formation contains sedimentary layers with distinctive carbonate nodules restricted to those layers. These nodules, which are most common on the western margin of the Lower Outwash Plain, were probably formed in a valley-flat environment following a break in deposition of the sediments. Later carbonates which occur as patches and nodules in horizons cross-cutting sedimentary layers, mark an important period of soil differentiation. Soils containing these horizons are referred to the soil stratigraphic unit called Loveday Soil.

Layers of red clay occur above Loveday Soil. These are well-developed on the Lower Outwash Plain. Fossil stream courses at the top of Pooraka Formation are marked by poorly-sorted deposits of angular quartz sand.

Soils of the Lower Outwash Plain are red-brown earths (RB3, RB5, RB6, RB7) and alluvial soils (AL). (See Fig. 2 and the Correlation Chart, Fig. 3.) The red-brown earths near the Para fault-line scarp contain red-brown clay of the thin clay layer over Pooraka Formation. The distinction between RB3 and RB5 depends upon thickness and structure of the thin clay layer. These soils do not contain the older clays and carbonates of the red-brown earths south of the Torrens River. Their closest affinities are with the soils RB6 and 7: Soil type RB7 is developed adjacent to soil type RB3 and 5 and differs only in the presence of more sand in the surface horizons or the absence of the red clay of the thin clay layer. Type RB6 differs from RB7 in that it is saline with a high groundwater table consequent on the rise of the Flandrian Sea. Alluvial soils are poorly differentiated quartz sands of the fossil stream courses. Similar soils of colluvial origin occur near the Para fault-line scarp, where they contain re-worked material from older brown soils in many places.

The Estuarine Plain

The Estuarine Plain is a flat-lying coastal tract containing thin marine gulf, estuarine and littoral deposits including the Lipson and St. Kilda formations. The deposits, which were laid down during the ingression of the Flandrian Sea, rest upon the eroded top of the Pooraka Formation and older units. Shell banks near the eastern margin of the plain mark the maximum advance of the Flandrian Sea. Red-brown dune sand derived ultimately from Pooraka Formation on the eastern margin of the plain was laid down upon St. Kilda Formation following a retreat of the sea. Alluvial and younger estuarine deposits are found in the western margin of the plain. Beach ridges and dunes containing Semaphore Sand fringe the modern coast.

Soils of the Estuarine Plain are solonchaks (So) and coastal sands (DS2). The solonchaks include eroded RB6 soils overlain by deposits of the St. Kilda Formation, and solonchaks in thicker sequence of St. Kilda Formation. Coastal sands are of two types: DS1 includes the red-brown Fulham Sand in the older dunes, and DS2 includes the younger Semaphore Sand of dunes fringing the modern coast.

CONCLUSIONS

This study demonstrates that the stratigraphic approach can be employed to advantage in the systematic study of soils, and thus supports the general theory set out in an earlier paper (Firman, 1968). The study also shows that soil profiles can be examined and described using "geological" and "pedological" methods, together with conventional pedological nomenclature. This is possible for two reasons: The first is that both methods have in common a detailed and objective description of materials naturally occurring in the field; the second is that the methods and nomenclature selected are those compatible with stratigraphic principles.

Stratigraphic analysis shows that "parent" materials, and the organized or emplaced layers stratigraphically associated with them, occur in sequence with

other horizons of similarly associated materials. The conclusion is that soil formation is periodic, and that layers in soils are formed in different ways at different times. One consequence of this conclusion is that the simple concept of profile differentiation from homogenous material is limited, possibly to the time of formation of individual layers. Another consequence is that stratigraphic correlation can be carried out with soils in much the same way as with other stratified materials.

The stratigraphic approach used in this study leads inevitably to a statement of soil evolution and to the recognition of parallel development of landform. This parallel development favours a matching of soil and landform chronology as a check on the history of soil development. Other consequences are, firstly, the recognition of the influence of profound events upon the formation of paleosols, genetic groups of soils and associated landforms, and, secondly, the correlation of soils formed in similar but widely separated environments.

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THE GENUS *MILTHA* (MOLLUSCA: BIVALVIA) IN THE AUSTRALIAN CAINOZOIC

BY N. H. LUDBROOK

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The genus lives at present off the southern coast of California and off the coast of Brazil in latitudes 8°-23°; Cainozoic occurrences are nearly all between latitudes 30° and 40°.

INTRODUCTION

Miltha is a genus of large disc-like lucinid bivalves with a restricted geographical distribution and very limited specific differentiation. Some thirteen species, most of which are represented by a few individuals, can be assigned to the genus in the strict sense. Only two are known to be living today—*Miltha childrenae* (Gray) from Brazil and *M. xantusi* (Dall) from Baja California. With two possible exceptions, one in the Paleocene of New Zealand and the other in the Californian Eocene, the genus first appears in the late Oligocene or Miocene of California, Florida, Argentina, New Zealand and Australia. Despite the paucity of specimens, *Miltha* is well represented in southern Australia from the Miocene to the Pleistocene.

Material used in the present study is in the collections of the Geological Survey of South Australia (GSSA), National Museum of Victoria (NMV), Geological Survey of Western Australia (GSWA), and the Western Australian Museum (WAM). I wish to thank the Director of Mines South Australia, the Director and Mr. T. A. Darragh of the National Museum of Victoria, the Director Geological Survey of Western Australia, and the Director and Dr. D. Merrilees of the Western Australian Museum for making it available. I am grateful also to Dr. A. G. Beu of the New Zealand Geological Survey for information on the New Zealand distribution of *Miltha*.

GENERIC CHARACTERS

The shell of *Miltha* in the strict sense is usually a large, slightly convex disc 70 mm. or more in diameter with a well developed posterior area separated from the rest of the shell by a radial ridge and slight flexure; the anterior area is relatively poorly defined by a shallow sulcus; the lunule is small, impressed, and tending to encroach upon the cardinal area; the ligament is long and sunken below the dorsal border; there are two cardinal teeth in each valve—3a and 3b in the right and 4b and 2a in the left—but no laterals. The posterior adductor is more or less oval, the anterior adductor long, extending nearly halfway across the shell adjacent to the pallial line.

The subgenus *Milthoidea* was erected by Marwick (1931), relying on Reeve's (1841) figure of *Lucina childreni* (*sic*) Gray, and with *Miltha neozelanica* Marshall & Murdoch as the type species, for forms having the posterior wing well developed, the long anterior muscular impression adjacent to the pallial line, the lunule small, deeply excavated and tending to obliterate the right anterior cardinal, and the attachment for the ligament broadly triangular. As *Miltha* has all of these characters, Chavan (1938) considered that *Milthoidea* should be synonymized with *Miltha*, with which I have previously expressed agreement (Ludbrook, 1955). The original material of the type species *Lucina childrenae* Gray has now been located in the Cracherode Shell Collection of the British Museum (Natural History) and the lectotype, Crach. No. 216, figured (Wilkins, 1957). Any doubts as to the nature of the shell characters which might have justified the subgenus are removed.

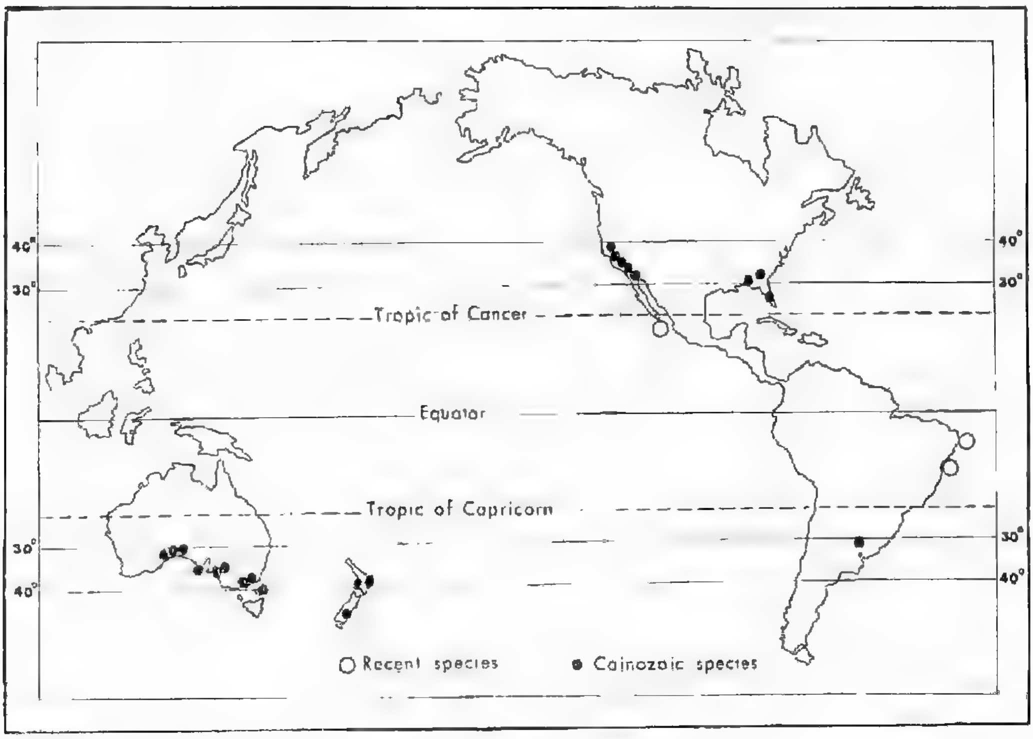

Fig. 1. Distribution of *Miltha*.

DISTRIBUTION

Fossil and living records of the genus are shown in Figure 1. With two exceptions they date from the late Oligocene or from the Miocene when it became well established in the Americas and in Australia and New Zealand.

Although the fragmentary nature of the material renders its location in the genus open to some doubt, the earliest record of *Miltha* is that of a small species, *M. agilis* Finlay & Marwick from the Wangaloa fauna (Paleocene) of New Zealand. According to Beu (1966) the genus then continues to the end of the Pliocene in New Zealand. Dr. Beu (in correspondence) has given the following ranges for the species: *M. agilis* Wangaloa fauna only; *M. dosiniformis* Marshall

and Murdoch Whaingaroan (early Oligocene) to Tongaporutuan (Upper Miocene) almost continuous; *M. neozelanica* Marshall & Murdoch Waitakian (late Oligocene or basal Miocene) to Waipipian (mid-Pliocene), rare, discontinuous, common only in Waipipian.

The genus is represented in the Eocene of California by *Lucina packi* Dickerson, placed in *Miltha* by Vokes (1939). From the Miocene to Pliocene it occurs in several formations in southern California (Grant & Gale, 1931), including the Temblor (Vaqueros of Arnold, 1909) Formation and the Monterey Shale (Woodring, Bramlette & Kew, 1946). The Miocene *M. sanctaecrucis* Arnold was placed in synonymy with the Pliocene—Recent *M. xantusi* (Dall) by Grant & Gale, but not by later authors. From the figures the two appear to be distinct, *M. sanctaecrucis* being more circular in outline like the Australian *M. flindersiana* and *M. hamptonensis.*

In Florida the Miocene-Pliocene record of *Miltha* is similar to that of California with *M. chipolana* (Dall) in the Chipola Formation and Oak Grove Sand of the Alum Bluff Group (Dall, 1903; Gardner, 1926) and *M. caloosaensis* (Dall) in the Pliocene Caloosahatchie Formation.

In South America *Miltha iheringiana* Doello-Jurado was described from the Miocene of Entre Rios, Argentina.

The record in Australia is also somewhat sporadic, with a maximum development in the Pliocene.

All Cainozoic occurrences except the Wangaloan *M. ogilis* in the South Island of New Zealand and the Caloosahatchie *M. caloosaensis* of Florida lie between latitudes 30° and 40°.

The two Recent species *M. childrenae* (Gray) and *M. xantusi* (Dall) are notable for their rarity. *M. childrenae* occurs off the Brazilian coast between latitudes 8° and 15°; it has been recorded from Recife (Pernambuco) and Salvador (Bahia). *M. xantusi* has been described as "one of the rarest as well as next to the largest of the West American lucines . . . known only by a few specimens, most of those taken off Cape San Lucas in depths of 30 or more fathoms" (Keen, 1958). The locality is approximately at 23° N.

The present surface temperature requirements of the genus appear to be within the range of 21° C. and 27° C., those of Cape San Lucas being February 21° August 27°, and of Brazil August 23° February 27° (Sverdrup, Johnson & Fleming, 1942, Charts II and III).

Discussions of the genus and its distribution are contained in Chavan (1938), Dall (1903, 1905), Gardner (1926), Keen (1958), Lamy (1920) with a synonymy of *M. childrenae,* Stewart (1930). Species from the European Eocene previously placed in *Miltha,* as well as *Lucina voorhoevei* Deshayes from Mozambique, doubtfully referred to *Miltha,* and several American species are now placed in such genera as *Eomiltha* and *Recticardo.*

AUSTRALIAN OCCURRENCES

Miltha was first recognized in Australia by Tate (1890) from fragments recovered from Dry Creek Bore. Fragments from Abattoirs Bore were subsequently described by N. H. Woods (1931) as *Dosinia grandis* (*non* Nelson, 1870), and later as *Miltha* (*Miltoidea*) *grandis* by Singleton & Woods (1934). An incomplete specimen from Flinders Island, Tasmania, "probably conspecific with the South Australian specimens" was separated as a subspecies *M.* (*M.*) *grandis flindersiana* Singleton & Woods. Cotton (1947) renamed the species *Miltoidea hora* (*nom. nov.* for *Dosinia grandis* Woods 1931 *non* Nelson, 1870), the species being relocated in *Miltha* by Ludbrook (1955, 1959).

The collection of further material from Flinders Island and from Gippsland Victoria, enabled Wilkins (1962) to extend the geographical range and the speciation of the genus. The Flinders Island subspecies was raised to specific rank and an internal mould and cast from Mitchell River, Gippsland, described as a subspecies *Miltha flindersiana dennanti*.

Miltha is now known to occur in the Lower Miocene Nullarbor Limestone, to be well represented in the Pliocene of the St Vincent and Murray Basins of South Australia and to survive to the Pleistocene of the Eucla Basin. Five species having stratigraphic utility are recognized: *Miltha nullarborensis* Ludbrook sp. nov. in the Nullarbor Limestone, *M. dennanti* Wilkins in the Mitchellian (Upper Miocene) of Gippsland, the Cheltenhamian Black Rock Sands and the Bookpurnong Beds (Lower Pliocene); *M. flindersiana* Singleton & Woods, the name on elevation to specific rank having priority over *M. hora*, in the Upper Pliocene of the Cameron Inlet Formation of Flinders Island, the Dry Creek Sands and the Norwest Bend Formation; *M. lindsayi* Ludbrook sp. nov. in the Norwest Bend Formation, the Dry Creek Sands and the Hallett Cove Sandstone; and *M. hamptonensis* Ludbrook sp. nov. in the Pleistocene calcareous sandstones of the Eucla Basin. All occurrences are in limestones, sandy limestones, quartz sands or sandstones, the best preserved specimens being in incoherent sands such as the Dry Creek Sands or the glauconitic sands of the Bookpurnong Beds. As almost all the well preserved specimens from South Australia occur in subsurface material recovered by percussion drilling, complete specimens are rare. Material from the Nullarbor Limestone and from limestones of the Norwest Bend Formation is always in the form of moulds and casts.

The present surface temperature requirements of *Miltha* and other genera with which it is associated in the Nullarbor Limestone and several of the Pliocene formations give confirmation to the frequently stated observations (e.g. Crespin, 1950, Ludbrook, 1954) that at certain times waters have been warmer in the Flindersian Province of southern Australia than they are today. The genus seems to have established itself in the Lower Miocene at a time when, without allowing for possible differences between water temperatures and palaeotemperatures (Dorman, 1966), water temperatures were in the vicinity of 23-25° and limestones carrying Indo-Pacific foraminifera were deposited.

During the Pliocene, the waters of the Flindersian Province in the restricted sense of Bennett and Pope (1953), that is, the coast of South Australia and the south coast of Western Australia, partly equivalent to Crespin's (1950) Austral Indo-Pacific Province, were probably warmer than those of the Maugean Province of Bennett and Pope (Bass Strait Province of Crespin), since large pearl shells (*Pinctada*) and *Anodontia* are associated with *Miltha* in the Bookpurnong Beds and the Dry Creek Sands. The westward retreat of *Miltha* to survive in the Pleistocene of the Roe Plain is not perhaps anomalous in view of the higher summer surface temperatures of the Great Australian Bight (20°) as compared with Bass Strait (16°) at the present time. Except for the Roe Plain occurrence, *Miltha* did not survive the cooling of waters at the end of the Pliocene. Its association with *Pinctada* suggests that it lived in the South Australian Pliocene at depths of 10 to 40 fathoms or more, comparable with the present habitat of *M. xantusi*.

None of the specimens from Victoria or Flinders Island reach the size of the South Australian and Western Australian forms. This is interpreted as confirming that the waters of the Maugean ("Bass Strait") Province were cooler than those of the Flindersian ("Austral Indo-Pacific") Province in Tertiary as well as in Recent times.

SYSTEMATIC DESCRIPTIONS

Genus MILTHA H. & A. Adams, 1857

Type species (monotypy) *Lucina childrenae* Gray

Miltha dennanti Wilkins

pl. 1, figs. 1-6

1962. *Miltha flindersiana dennanti* Wilkins, 43, pl. 5, figs. 3, 4

Shell large, solid, convex, slightly inequilateral, about as long as high, subcircular, posterior margin truncated, nearly straight, anterior and ventral margins rounded, posterior area well developed and marked by a radial sulcus and slight flexure; umbos small, slightly incurved, prosogyrous, situated slightly to the anterior, lunule small, deeply impressed and extending over part of the anterior cardinal, ligament deeply sunken below the dorsal margin; surface ornamented with numerous concentric threads and obscure radial striae visible in oblique light, concave anteriorly, more conspicuous in the lower half of the shell in the posterior one-third and obsolete elsewhere; between the concentric threads there are numerous microscopic radial striae; a weak shallow radial sulcus concave towards the anterior over which the concentric threads tend to become irregular.

Hinge plate fairly straight, wide, right valve with a small narrow anterior cardinal and a curved posterior cardinal; left valve with a strong triangular broadly grooved anterior and a long, narrow, curved posterior cardinal; resilium area long, fairly broad, triangular; posterior adductor oval, anterior adductor long, parallel to the pallial line on the lower edge and nearly straight on the upper edge, a small deep pedal retractor pit just above the anterior adductor; area within the pallial line thickened with a deposit of secondary calcite divided by a high umbonal-posterior ridge and a furrow extending from about the middle of the ridge to the lower part of the anterior adductor, area below the furrow pitted more strongly than elsewhere.

Dimensions: Hypotypes in the Geological Survey of South Australia Collection vary in length from 74 to 85 mm., in height from 73 to 84 mm., inflation from 15 to 20 mm. (single valve).

Type locality: Bellevue, Mitchell River, Victoria; Mitchellian.

Material: Casts of the holotype NMV P22320-1; 41 specimens: NMV P22801-40 Bentleigh, Victoria; GSSA M1340, M2762, M2774a,b.

Distribution: Mitchellian of Bellevue, Mitchell River; Black Rock Sands (Cheltenhamian); Bookpurnong Beds (Cheltenhamian); Upper Miocene to Lower Pliocene.

Miltha flindersiana Singleton & Woods

pl. 2, figs. 1-6

1931. *Dosinia grandis* N. H. Woods, 148, pl. 7, figs. 5,6 (*non* Nelson, 1870).
1934. *Miltha (Milthoidea) grandis*; Singleton & Woods, 208, pl. VIII, figs. 1-3.
1934. *Miltha (Milthoidea) grandis flindersiana* Singleton & Woods, 210, pl. VIII, fig. 4.
1938. *Miltha grandis*; Chavan, 230.
1947. *Milthoidea hora* Cotton, *nom. nov.* for *Dosinia grandis* Woods *non* Nelson.
1955. *Miltha hora* (Cotton); Ludbrook, 53; 1959, Ludbrook, 220.
1962. *Miltha flindersiana*; Wilkins, 43, pl. 5, figs. 1,2.

In describing *M. flindersiana* from a single worn valve from a bore on Flinders Island, Singleton and Woods recognized that it was probably conspecific with the South Australian Pliocene shell originally described as *Dosinia grandis*, and that the differences were perhaps partly due to age. Ludbrook (1955) considered a juvenile from Hindmarsh Bore conspecific with the Flinders Island holotype of *M.* (*M.*) *grandis flindersiana* "probably also a juvenile". The range of specimens now available from Flinders Island and from the Dry Creek Sands clearly demonstrates that *M. flindersiana* is conspecific with *M. hora* over which it has nomenclatural priority. The Flinders Island specimens apparently never grew to the size of adults from South Australia.

The species was fully described by Singleton and Woods (1934). It may be distinguished from other species by its more circular shape, its finer ornament and the flatness of the disc.

Type locality: No. 1 Bore, Wingaroo, Flinders Island, Tasmania, 55-80 feet (16·7-24·3 m.), ?Upper Pliocene.

Material: 3 pairs and 16 valves from dam excavations on Furneaux Estate, NMV P26886, P26887; 6 valves and 7 fragments from bores in the metropolitan area Adelaide, GSSA M304-7, M2227, M3197, M3201,3203; 7 internal casts and moulds from Fishery Bay and Ramco GSSA M3203,3204,3209. Internal casts from Fishery Bay, Eyre Peninsula, hundred of Sleaford, section 11, are all flat, and so far as can be determined in the absence of external moulds, belong to *M. flindersiana*. Internal moulds on limestone of the Norwest Bend Formation at Ramco appear also to be *M. flindersiana*.

Distribution: Upper Pliocene of the Cameron Inlet Formation, Flinders Island, Tasmania; of the Dry Creek Sands, St. Vincent Basin, and of the Norwest Bend Formation, Murray Basin, and sandy limestones of Fishery Bay.

Miltha hamptonensis Ludbrook sp. nov.

pl. 3, figs. 1-3; pl. 4, figs. 1,2

Shell large, thick, nearly circular in outline, slightly inequilateral, left valve slightly convex, right valve nearly flat, both posterior and anterior margins rounded, the anterior more so than the posterior; posterior area poorly developed, narrow, and marked by a very slight flexure; umbos small, sharp, prosogyrous, situated a little to the anterior, lunule deeply impressed and thinly transgressive over the hinge area, ligament deeply sunken below the dorsal margin; surface ornamented with concentric lamellae 2 mm. apart with smooth interspaces but for occasional fine concentric striae. There is a shallow curved radial sulcus and corresponding flexure in the ventral margin of the left valve, in the right valve it is a slight radial ridge and flexure.

Hinge plate relatively narrow, somewhat irregularly curved, with a long thin posterior cardinal and high grooved anterior cardinal in the left valve, a high grooved posterior cardinal and small narrow anterior cardinal in the right valve; resilium area long, narrow, deep; posterior adductor oval, anterior adductor long, well separated from the pallial line; pedal retractor confluent with the anterior adductor; area within the pallial line moderately thickened, a high subumbonal-posterior ridge and a short anterior ridge below the hinge plate, a weak furrow from the middle of the posterior ridge to the lower part of the anterior adductor. Inner margin broad, nearly flat, radially striated.

Dimensions: Holotype length 91, height 85, inflation (both valves) 32 mm.

Type locality: Hampton Microwave Repeater Site, 33 miles east of Madura, latitude 31° 57′ 57″, longitude 127° 34′ 45″.

Material: Holotype (a pair) WAM 69·334, WAM 61·33, GSWA F7052 (fragments of 2 valves).

Distribution: Pleistocene of the Roe Plain, Western Australia.

Miltha lindsayi Ludbrook sp. nov.

pl. 5, figs. 1-7

Shell large, rather thin, chalky, gently convex, slightly inequilateral, posterior margin obliquely truncated, anterior and ventral margins rounded; posterior area well developed and marked by a shallow radial sulcus and flexure; umbos small, very slightly incurved and prosogyrous, situated a little to the anterior, lunule deeply impressed and transgressive over the hinge area, ligament deeply sunken below the dorsal margin; surface ornamented with conspicuous concentric lamellae about 1 mm. apart with microscopic concentric threads between them, median radial sulcus not usually present.

Hinge plate relatively narrow and long, curved, with a high posterior cardinal and small anterior cardinal almost obscured by the lunule, resilium area long and narrowly triangular, longitudinally striate and bordered on its lower edge by a slight ridge from which it is inclined backwards from the surface of the hinge plate. Posterior adductor subovate, anterior adductor long, pedal retractor apparently confluent with the anterior adductor; area within the pallial line filled with secondary calcite, divided into more or less triangular areas by a posterior ridge and furrow and a median furrow below which the surface is conspicuously pitted; inner margin wide, obscurely striate towards the pallial line.

Dimensions: Holotype GSSA M2747 length (estimated) 67, height 70, inflation (both valves) 30 mm.; other specimens length from 64 to 74 mm., height 63 to 75 mm.

Type locality: Jervois Punt approach, Tailem Bend, South Australia. The locality has now been covered by road works at the approach to the punt landing; Norwest Bend Formation, Upper Pliocene.

Material: Holotype GSSA M2747 (a pair), paratypes M3205, M3206, and fragments; M3208 fragmentary material from the Hallett Cove Sandstone.

Distribution: Norwest Bend Formation at Tailem Bend; Hallett Cove Sandstone ½ mile east of Hallett Cove; Dry Creek Sands, where it overlaps with *M. flindersiana*. The Tailem Bend specimens are chalky and fragile. The specimen M303 from the Dry Creek Sands of Hindmarsh Bore is a thick solid shell with the truncated posterior margin and conspicuous ornament of *M. lindsayi*; the posterior adductor is more elongate and the hinge plate wider than in the more fragile forms of the species.

The species is named in honour of J. M. Lindsay, Assistant Senior Palaeontologist of the Geological Survey of South Australia, who collected the type material.

Miltha nullarborensis Ludbrook sp. nov.

pl. 4, figs. 3-6

The species is known only from external and internal moulds and casts.

Shell small for the genus, subcircular, only moderately compressed, slightly inequilateral, longer than high, posterior area well developed, defined by a prominent radial sulcus and flexure, umbo small, prosogyrous, lunule small, deeply impressed, and tending to encroach on the anterior cardinal, ligament sunken

below the dorsal margin; ornament of evenly spaced, fine, concentric lamellae about 1 mm. apart with microscopic radial threads between.

Hinge of moderate width with a strong anterior cardinal and a long narrow posterior cardinal; posterior adductor roundly quadrate, anterior adductor long and running parallel to the pallial line, pedal retractor impression a small deep pit just above the anterior adductor; radial ridges and furrows rather poorly developed; inner margin broad, smooth.

Dimensions: Holotype GSWA F6871/1 length 49, height 48 mm.

Type locality: "140-mile quarry", 6 miles southwest of Forrest, Western Australia; Nullarbor Limestone.

Material: 8 specimens, mostly internal casts and external moulds in hard limestone from "140-mile quarry" and Naretha, Western Australia; Watson Quarry and Lake Yarle, South Australia.

Distribution: Nullarbor Limestone (Lower Miocene) of the Eucla Basin.

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EXPLANATION OF PLATES

All figures natural size

PLATE 1

Miltha dennanti Wilkins

1,4. GSSA M1340, left valve, Loxton 5-10 feet (1·52-3·04 m.) below bed of River Murray; Bookpurnong Beds, Lower Pliocene.
2. NMV P22803, left valve, dump of excavations for sewerage tunnel 40 feet (12·11 m.) from surface, Beech and Wright Streets, Bentleigh, Victoria; Black Rock Sands, Cheltenhamian.
3. NMV P22808, right valve, same locality.
5. GSSA M2274b, right valve, A.O.G. Loxton No. 1 Well, 100-105 feet (30·48-32·00 m.); Bookpurnong Beds.
6. GSSA M2762, right valve, same locality.

PLATE 2

Miltha flindersiana Singleton and Woods

1. GSSA M305, Cowandilla Bore 470-485 feet (143·25-147·8 m.); Dry Creek Sands, Upper Pliocene.
2. NMV P26887, left valve, dam on Hills Block 52, Furneaux Estate Section B, 1·0 mile NNE of The Dutchman, Flinders Island; Cameron Inlet Formation, Upper Pliocene.
3-5. NMV P22886; 3, 5, right valve; 4, left valve; dam on Block 47, Furneaux Estate, Section B, Flinders Island; Cameron Inlet Formation, Upper Pliocene.
6. GSSA M2227, right valve, Kooyonga Golf Club Bore 15/62, 502 feet (153 m.); Dry Creek Sands, Upper Pliocene.

PLATE 3

Miltha hamptonensis Ludbrook sp. nov.

1. Holotype WAM 69·334 right valve of a pair of valves, Hampton Microwave Repeater Site, 33 miles east of Madura, Western Australia; Pleistocene.
2,3. Paratype, juvenile, WAM 61·33, 20 miles east of Madura; Pleistocene.

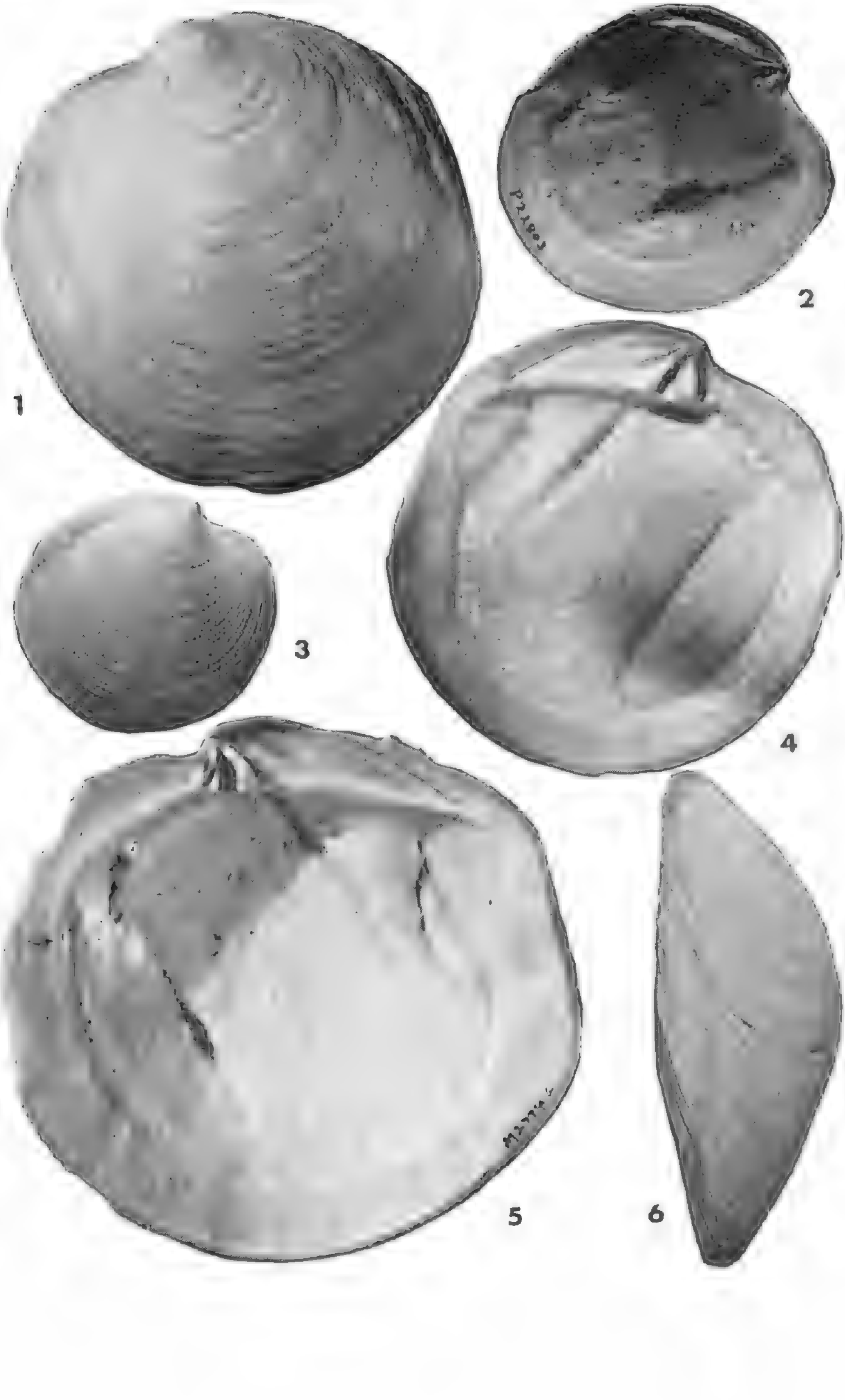
PLATE 4

1,2. *Miltha hamptonensis* Ludbrook sp. nov.
Holotype WAM 69·334 internal views; 1, left valve; 2, right valve, Hampton Microwave Repeater Site, 33 miles east of Madura; Pleistocene.
3-6. *Miltha nullarborensis* Ludbrook sp. nov.
3, paratype GSSA 3199a, Watson Quarry, South Australia, Nullarbor Limestone Lower Miocene; 4, paratype GSSA 3198a Naretha, Western Australia, Nullarbor Limestone; 5, holotype GSWA F6871/1 "140-mile quarry", 6 miles southwest of Forrest, Western Australia, Nullarbor Limestone; 6, paratype GSSA 3199b, Watson Quarry.

PLATE 5

Miltha lindsayi Ludbrook sp. nov.

1. Holotype (a pair) GSSA M2747, Norwest Bend Formation, Tailem Bend, South Australia; Upper Pliocene.
2,3. Paratype GSSA M3205, right valve, Tailem Bend.
4,5. Paratype GSSA M303, right valve, Hindmarsh Bore 450-487 feet (137-148 m.); Dry Creek Sands.
6,7. Paratype GSSA M304, left valve, juvenile, Bore 20 Woodville South; Dry Creek Sands.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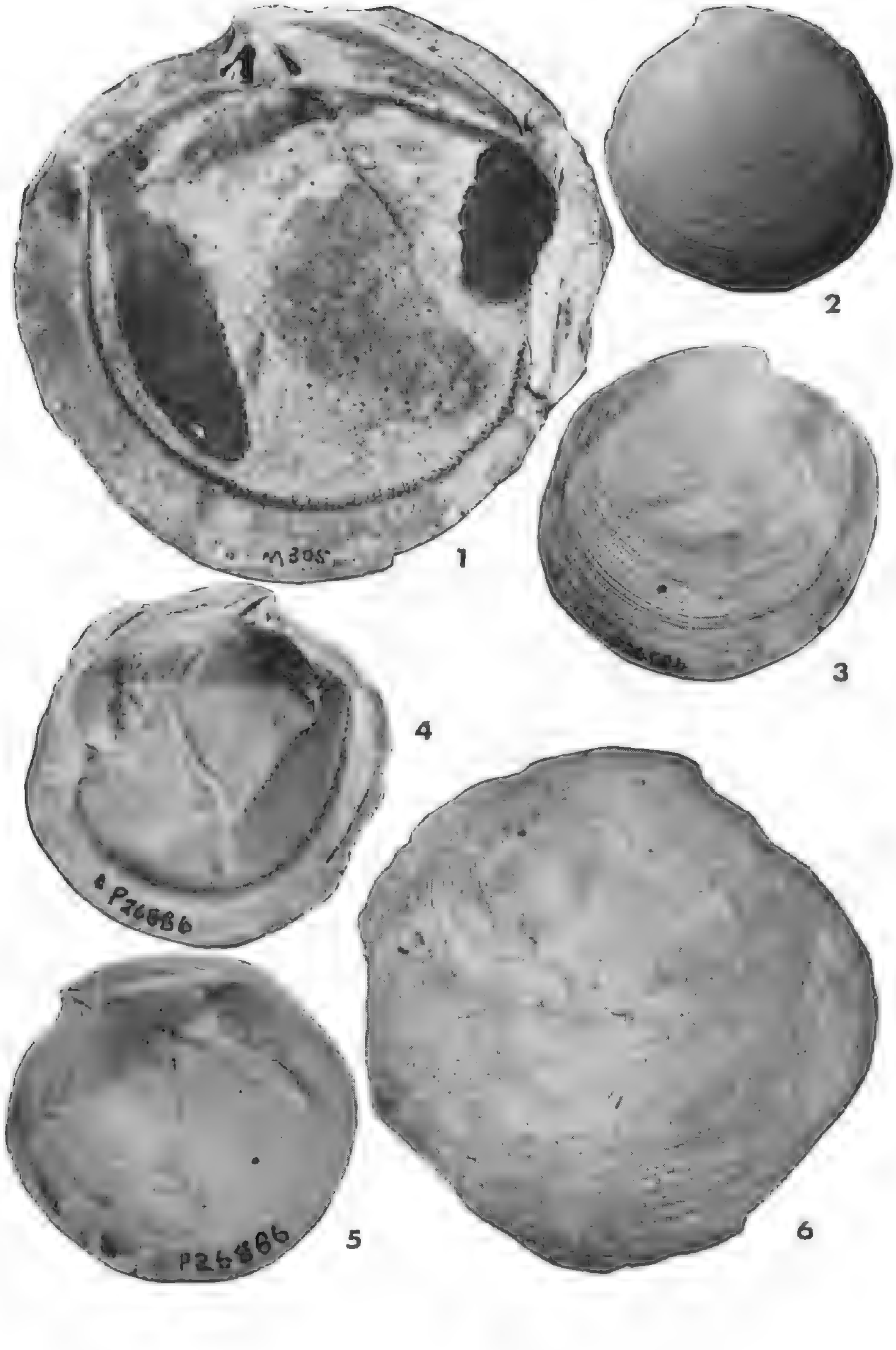
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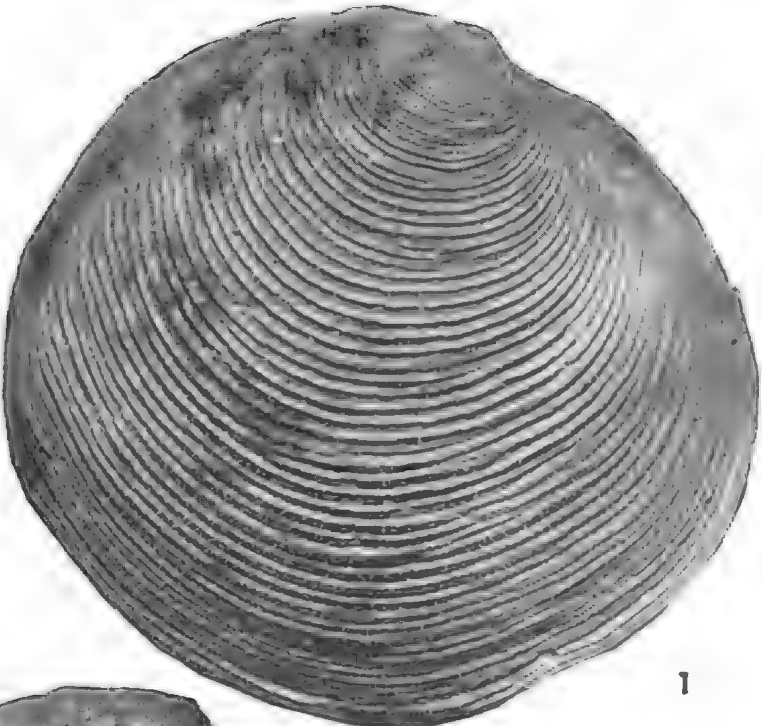

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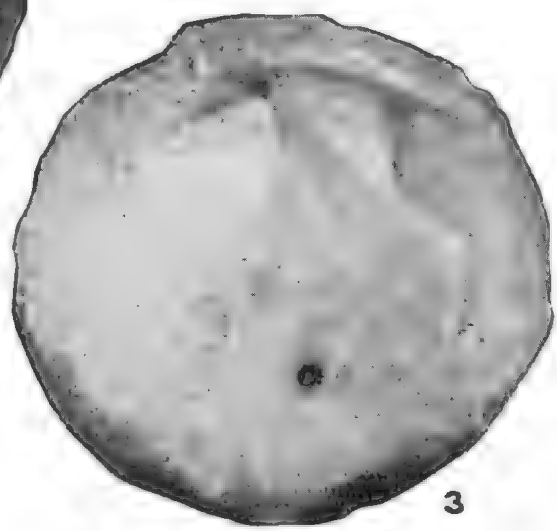

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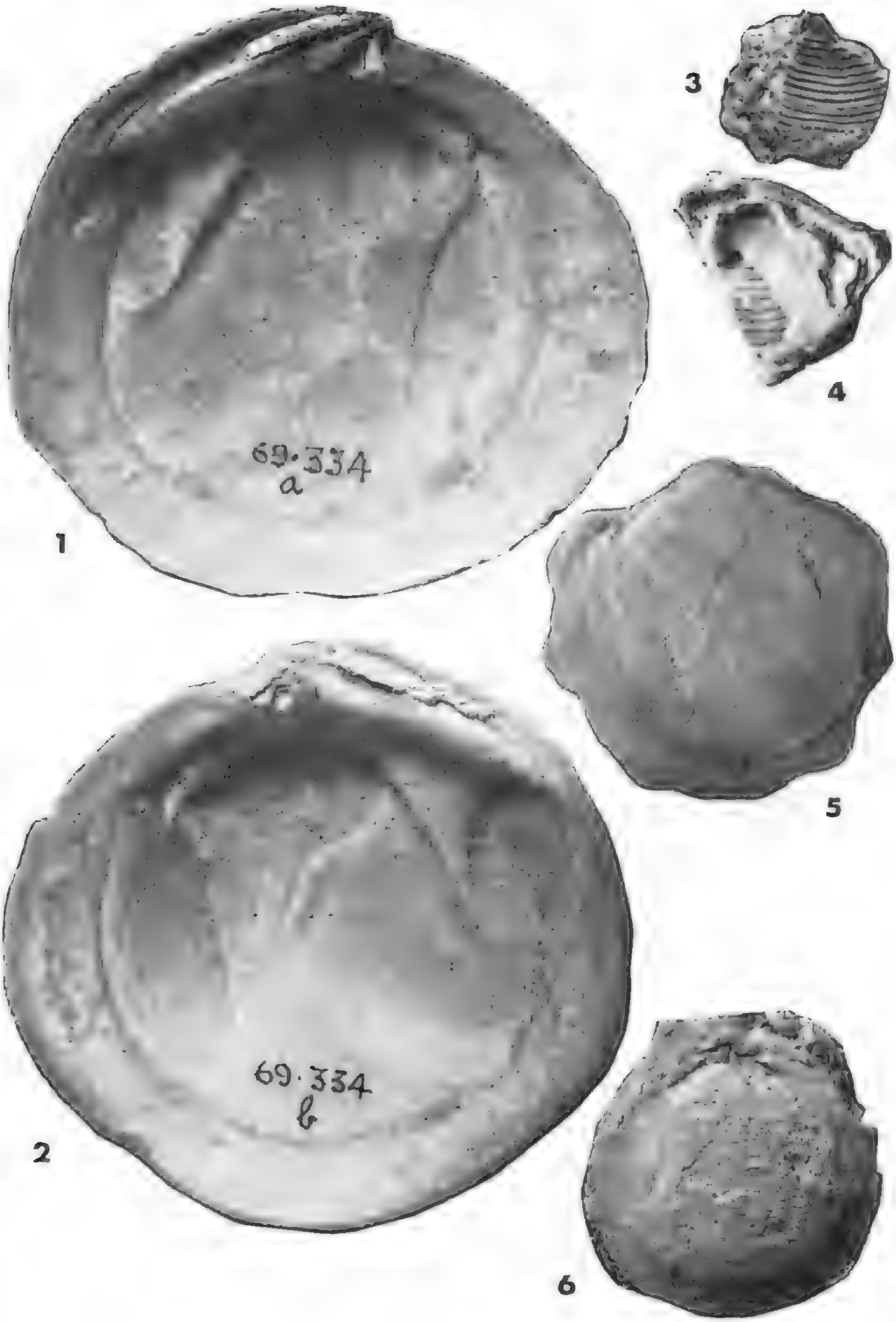
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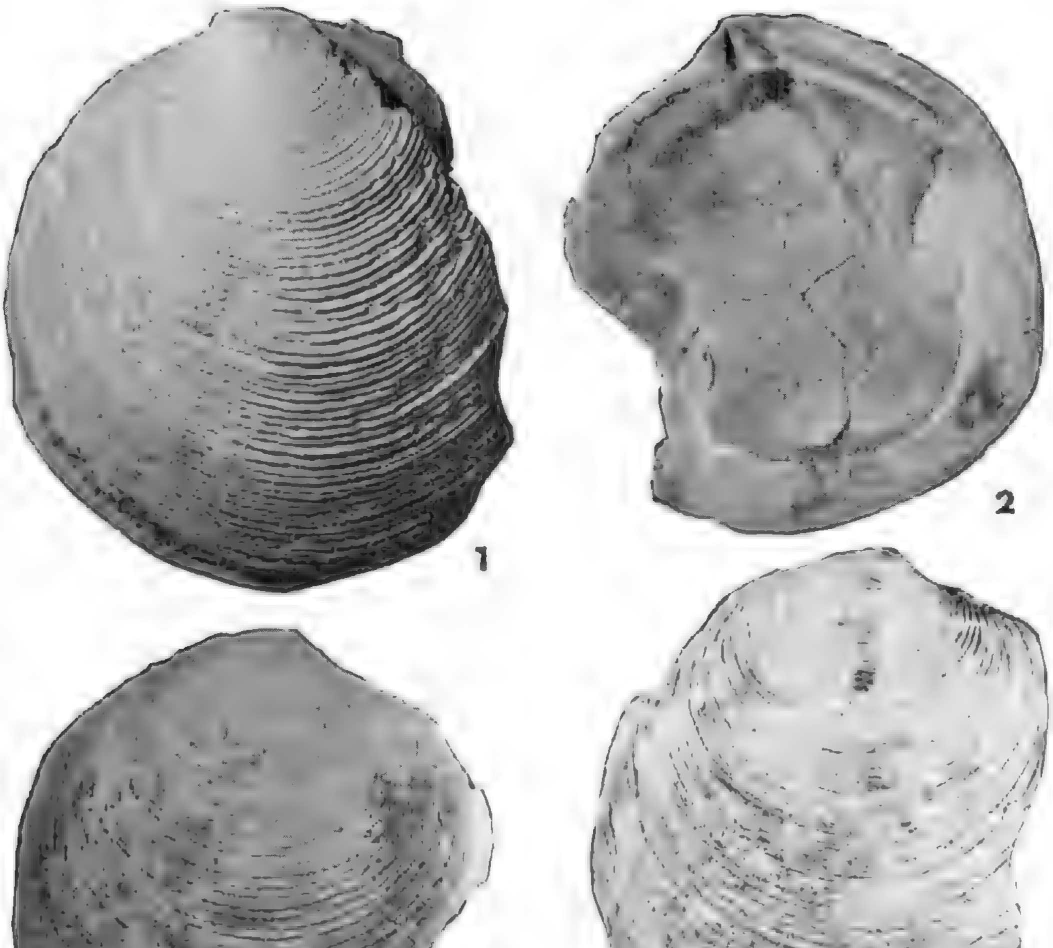
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SOIL SALINITY IN SALTBUSH COUNTRY OF NORTH-EASTER SOUTH AUSTRALIA

*BY R. W. JESSUP**

Summary

A total of 798 soil samples, collected at three different times, were analysed for chlorides. Of these 498 were also analysed for total soluble salts. The samples came from profiles of desert loams in two adjoining paddocks, one supporting saltbush and bluebush shrub-steppe, the other denuded of bush by excessive grazing. The bushes concentrate chlorides in the topsoil under their canopies. This chloride is derived from the soil below and between the bushes and is apparently released from dead leaves that collect under the canopies. There is a progressive increase in chlorides in the topsoil under the bushes and decrease in the surrounding soil during dry periods.

Eroded soils ("scalds") occur in the country denuded of bush. Chloride concentration in the surface of some "scalds" is higher than in equivalent horizons of uneroded soils. Also, less chloride occurs in some soils adjacent to the "scalds" than elsewhere. Apparently chloride has migrated into the "scalds7' from these depleted soils.

The distribution of chlorides and of total soluble salts down the profiles shows that there is no significant water movement in the uneroded soils below depths of between 18 in. and 24 in., and in the "scalds" below depths of between 1 in. and 6 in. Measurements of the amount of water held in the soils at field capacity, considered in relation to the rainfall regime, support this conclusion.

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[Read 10 July 1969]

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INTRODUCTION

In Australia little information is available concerning the effects of the native vegetation on soil properties. The main purpose of the present study was to determine whether bladder saltbush (*Atriplex vesicaria*) and the bluebush (*Kochia astrotricha*), two shrubs that are widely distributed in the southern part of the arid zone, influence the distribution of soluble salts in the soils on which they grow.

The area selected for investigation is in north-eastern South Australia about 30 miles north of Olary, on a plain that was originally entirely covered by shrub-steppe vegetation dominated by saltbush, but with scattered plants of bluebush. However, excessive grazing by stock in the first decade of this century caused complete destruction of the shrub-steppe in part of the area and its replacement by two plant communities, one dominated by grasses and the other by species of *Bassia*. Wind erosion during dry times, when the soil was inadequately protected by these two communities, resulted in an intricate pattern of "scalds" developing on the soil surface. In the "scalds" the topsoil was removed and the clay B horizon exposed.

In order to determine whether saltbush and bluebush affect the distribution of soluble salts, soil samples were collected under the bush canopies, between the bushes, and under both the grass and *Bassia* communities. In addition, samples were taken from the "scalds" so that the salinity of the eroded soils could be compared with that of the uneroded ones.

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THE SALTBUSH COMMUNITY AND THE SOILS SUPPORTING IT

Salinity of the soils supporting a well-preserved stand of saltbush shrub-steppe was investigated on Kalabity Station 0·5 miles south-south-east of the abandoned Telechie homestead. The saltbush and bluebush species present grow to an average height of 15 in. and a canopy diameter of 19 in. They are shallow rooting shrubs, with their roots confined to the upper 24 in. of the soil. The canopies of adjacent bushes are usually separated by distances of 1 to 3 feet. The soil between the bushes is devoid of plants during periods of prolonged drought, but the rainfall (Table 2) during the two years preceding the period when the first samples were collected, had resulted in the growth of *Bassia uniflora*, *B. decurrens*, *Enneapogon avenaceus* and other plants between the bushes (Table 1).

TABLE 1

Botanical composition of the plant communities. The species nomenclature is that of Black (1948). Botanical composition was determined by counting the number of plants of each species in randomly distributed metre quadrats.

	Saltbush community %	Grass community %	*Bassia* community %
Atriplex vesicaria	20·9	0	0
Bassia uniflora	32·9	1·0	6·4
Bassia ventricosa	1·0	0·9	21·3
Enneapogon avenaceus	24·1	88·4	12·1
Bassia decurrens	12·0	2·4	42·5
Kochia astrotricha	2·5	0	0
Malococera tricornis	1·1	0	0
Atriplex limbata	1·8	0	0·7
Sida intricata	1·2	3·1	9·5
Eragrostis dielsii	1·3	3·5	0·4
Stipa nitida	1·0	0·7	0·7
Bassia divaricata	0·3	0	0
Bassia brachyptera	0	0	0·7
Bassia paradoxa	0	0	2·1
Bassia biflora	0	0	0·7
Babbagia acroptera	0	0	2·8

The saltbush community occurs on soils known as desert loams. These soils have texture contrast profiles with shallow, loamy, brown to red A horizons clearly separated from the red, clay B horizons in which there are accumulations of carbonates. The desert loams have an alkaline reaction, are moderately to strongly saline, and have calcium and magnesium as the main exchangeable cations.

Two types of desert loam profiles occur in the area investigated. The most widespread one, referred to as type X, has the following characteristics:

Superficial deposit: A layer of wind-blown sand, 1 in. thick between the bushes and about 4 in. thick under them, overlies the soil profile. The sand is red (2·5 YR 5/6 — 5/8*), has false bedding and is clearly separated from the A horizon of the soil.

A horizon: 6 in. thick. Yellowish red (5 YR 4/6 — 5/6); sandy loam (CS 53%, FS 33%, Si 6%, C 9%); massive. Soft when dry; a little sub-angular gravel; pH 8·6; exchangeable cations—Ca 52%, Mg 28%, Na 6%, K 15%. Sharp boundary to:

* All Munsell colour notations are for soil in the dry state. Consistence terms as defined in the U.S.D.A. Soil Survey Manual (1951) are used. Abbreviations used in the descriptions are CS = coarse sand, FS = fine sand, Si = silt, and C = clay. Exchangeable cations are expressed as percentage of total cations.

B_1 horizon: 10 in. thick. Yellowish red to red (5 YR 4/6 — 2·5 YR 4/6); light clay (CS 33%, FS 21%, Si 7%, C 36%); massive. Slightly hard when dry. Slightly plastic and slightly sticky when wet; a little sub-angular gravel. pH 9·1; exchangeable cations—Ca 54%, Mg 26%, Na 14%, K 6%. Diffuse boundary to:

B_{ca} horizon: Red (2·5 YR 4/6 — 5/8); clay (CS 27%, FS 20%, Si 11%, C 41%); massive. Slightly hard to hard when dry, plastic and sticky when wet; a little sub-angular gravel; many pockets of soft carbonate and much carbonate in the fine earth ($CaCO_3$ 15%); pH 9·8; exchangeable cations —Ca 39%, Mg 32%, Na 26%, K 3%.

Small areas of soil, referred to as type Y, occupy the slightly lower sites on the plain. This soil has the following characteristics:

Superficial deposit: A layer of wind-blown sand, 1 in. thick between the bushes and about 4 in. thick under them, overlies the soil profile. The sand has false bedding and is clearly separated from the A horizon of the soil.

A horizon: 3 in. thick. Light red (2·5 YR 6/6) to red (2·5 YR 5/6); sandy loam (CS 46%, FS 39%, Si 9%, C 7%); massive; soft when dry; often with a little sub-angular gravel. pH 8·9; exchangeable cations—Ca 48%, Mg 26%, Na 9%, K 17%. Sharp boundary to:

"Bleached" top of B horizon: Up to ½ in. thick. Reddish yellow (5 YR 6/6 — 7/8); vesicular; light clay. Slightly hard when dry, slightly plastic and slightly sticky when wet.

B_1 horizon: 7 in. thick. Red (2·5 YR 4/6 — 4/8); light clay (CS 30%, FS 26%, Si 7%, C 37%); prismatic structure, the prisms (1½-3 in. across) breaking fairly easily to sub-angular blocky peds ¼-½ in. in size; slightly hard to hard when dry, plastic and sticky when wet; a little sub-angular gravel. pH 9·1; exchangeable cations—Ca 35%, Mg 36%, Na 26%, K 3%. Diffuse boundary to:

B_{ca} horizon: Red (2·5 YR 4/6 — 5/8); clay (CS 21%, FS 19%, Si 11%, C 47%); massive; slightly hard to hard when dry, plastic and sticky when wet; a little sub-angular gravel; many pockets of soft carbonate and much carbonate in the fine earth ($CaCO_3$ 19%), pH 8·9; exchangeable cations —Ca 35%, Mg 36%, Na 26%, K 3%.

The type Y soil has a shallower A horizon and hence a finer-textured profile than the type X soil, and has higher exchangeable sodium and better structure in the B_1 horizon. The type Y soil also has higher salinity. These differences in profile features are probably due to the fact that the type Y soil occurs on the slightly lower parts of the plain.

VEGETATION AND SOILS IN THE COUNTRY DENUDED OF SALTBUSH

The site selected for the study of soil salinity in country denuded of its saltbush cover, was in Watercourse Paddock on Bimbowrie Station, south of and adjoining the well-preserved stand of saltbush discussed above. The vegetation in Watercourse Paddock consisted of an intricate pattern of two plant communities, one dominated by the grass *Enneapogon avenaceus* and the other by two species of *Bassia* (*B. decurrens* and *B. ventricosa*). The floristic composition of these two communities is shown in Table 1. The grass community occupied 80% of the area and the *Bassia* community 10%. The remaining 10% was devoid of plants.

In the unvegetated areas ("scalds") the A horizon of the soils had been removed by wind erosion and the exposed B horizon was irregularly veneered

TABLE 2

Rainfall (in inches) preceding and between the periods of sampling. The first sampling was carried out during the period 19/5/57 – 12/6/57, the second 28/8/57 – 11/9/57, and the third 23/10/59 – 6/11/59. No rain fell during the sampling periods.

	1954	1955	1956	1957	1958	1959
January	0·24	1·04	1·36	0·00	1·32	0·50
February	0·00	4·50	0·88	0·37	0·33	0·00
March	0·26	2·07	2·81	0·45	1·17	0·48
April	0·52	0·16	0·36	0·14	0·45	0·00
May	0·15	3·27	0·71	0·00	0·42	1·00
June	0·26	1·29	0·92	1·55*	0·00	0·00
July	0·00	0·52	2·20	0·00	0·55	0·37
August	0·00	0·84	0·14	0·26	1·25	1·05
September	0·00	1·33	0·09	0·00	0·23	0·33
October	0·90	0·21	0·39	0·07	2·34	0·66
November	0·00	0·92	0·05	0·00	2·24	0·00
December	2·92	0·00	0·07	1·31	0·70	—
Year	5·31	16·15	9·98	4·15	11·00	—

*1·45 in. fell on June 19-20.

with a lag deposit of gravel. The coarse-textured materials stripped from the "scalds" had accumulated around their margins. Thus in Watercourse Paddock there were areas of uneroded, truncated and of buried types X and Y profiles. The grass community occurred on the uneroded type X soil and on the aeolian deposits.

SOIL SALINITY

Soil samples were collected at three different times, the first in May-June 1957, the second August-September 1957 and the third in October-November 1959. Very little rain had fallen during the 10 months prior to the first sampling period (Table 2). The soils were very dry, in fact tests carried out in the laboratory showed that field moisture was less than that held in the soil at a tension of 15 atmospheres, commonly referred to as the permanent wilting point of plants (Table 3).

TABLE 3

Soil water data derived from laboratory determinations carried out by O. B. Williams, C.S.I.R.O., Division of Animal Physiology, Parramatta, N.S.W.

		Inches of water per stated depth held in the soil		
Soil type	Depth (in.)	At field capacity	At 15 atmospheres tension	At first sampling time in field
X	0–3	0·60	0·11	0·03
	3–9	0·87	0·27	0·11
	9–18	2·58	1·62	1·04
Y	0–3	1·41	0·12	0·03
	3–9	1·34	1·24	0·49
	9–18	2·01	1·90	0·93
	18–24	1·64	1·34	0·83
	24–30	1·39	1·34	0·89

Field soil moisture was not determined at the time of the second and third samplings. There was one heavy fall of rain (about 1·50 in.) soon after the first sampling (Table 2), but following this and prior to the second sampling there was a period of about 2½ months when very little rain was recorded. The soils were again dry at the time of the third sampling. During the three months prior to this last sampling there was little rain except for one fall of 0·62 in. recorded about 6 weeks prior to sampling time.

Method of sampling

During the first sampling (May-June 1957) the samples were taken at depths of 0-1, 5½-6½, 11½-12½, 17½-18½ and 23½-24½ in. in each profile. For the purpose of discussion, these depths, which include the superficial sand deposit, are referred to as 0-1 in., 6 in., 12 in., 18 in., and 24 in. respectively. Nine profiles of uneroded type X soil, each at least 9 in. away from the nearest bush canopy, were sampled in the shrub-steppe. These sites are referred to as "between bushes" in Tables 4 and 5. Nine profiles of uneroded type X soil were also sampled under the saltbush canopies, and six profiles of uneroded type Y soil under bluebush canopies. In addition, nine profiles each of uneroded type X soil supporting grass, uneroded type Y supporting the *Bassia* community, and "scalded" type Y devoid of vegetation, were sampled in the country denuded of its saltbush cover.

In the second sampling (August-September 1957) samples were collected at depths of 0-1, 5½-6½, 11½-12½, 17½-18½, 23½-24½, 35½-36½, 47½-48½, 59½-60½ and 71½-72½ in. in each profile. All profiles were of uneroded type X soil in the shrub-steppe country. Nine profiles were sampled under both the saltbush and the bluebush canopies, and nine between the bushes.

The third set of samples taken in October-November 1959 were collected at the same depths as the first 1957 sampling. Twelve profiles of uneroded type X soil were sampled in the shrub-steppe in each of three situations, namely under saltbush canopies, under bluebush canopies and between the bushes. Six profiles of uneroded type Y soil were also sampled between the bushes. In the country denuded of its bush cover, six profiles were sampled in the bare "scalds" of both X and Y soils, and six in an area supporting the grass community, adjoining the type X "scald", where 10 in. of sand had accumulated on the same soil type.

Methods used in the laboratory and statistical analyses

The 255 samples collected during the first sampling and the 243 samples from the second sampling were analysed for both chlorides and total soluble salts. The 300 samples from the third sampling were only analysed for chlorides. The chemical analyses were carried out using the methods described by Piper (1942), namely chlorides by electrometric titration and reported as percent sodium chloride present in air dry soil, and total soluble salts by electrical conductivity of a 1 : 5 soil : water suspension.

During the statistical examination of the analytical data it was found that it was necessary to transform the chloride and total soluble salt concentrations to $\log_{10}$ in order to stabilize the variation between the different samples taken at each depth. These $\log_{10}$ figures were always used when determining whether there were significant differences between the various sites.

Results

The analyses show that the type X profile contained less chloride than the type Y profile. During the first sampling (Table 4) the type X profile sampled in the grass community, had a significantly lower chloride concentration at depths of 6 in., 12 in. and 18 in. than the type Y profile sampled in the *Bassia* community.

Similarly, at the time of the third sampling, there was a higher concentration at depths of 0-1 in., 6 and 12 in. in the "scald" of the type X soil than at 6, 12 and 18 in. respectively in the uneroded soil between the bushes. Comparisons must again be made between these depths in the "scalded" and uneroded soils, because the eroded type X profile had lost about 7 in. of topsoil.

The additional chloride in this type X "scald" could have been derived from the soil nearby. During the third sampling, samples were taken from an area adjoining the type X "scald" where sand that had been stripped from the "scald" had accumulated. Beneath the deposit of sand, which was 10 in. in thickness, was uneroded type X soil. There were no significant differences in the chloride concentrations at depths of 12 and 18 in. in the areas where the sand had accumulated compared with depths of 0-1 and 6 in. respectively in the soil between the bushes. However, there was significantly less chloride at a depth of 24 in. where the sand had accumulated than at 12 in. in the soil between the bushes. This may indicate that there had been some loss of chloride from the buried type X soil adjacent to the "scald".

The depth of normal moisture penetration in the soils is indicated by the distribution of chlorides in their profiles. The chloride concentration reached a maximum at 24 in. and was not significantly different at any depth below. This shows that there was no significant water movement in this soil below a depth of between 18 and 24 in. In the "scalds" that were sampled the chloride concentration was constant at and below a depth of 6 in.; this indicates that water normally penetrated to less than 6 in. in these eroded soils.

Total soluble salts were not determined in the samples collected during October-November 1959, but the salt figures for the other two samplings (Tables 5 and 7) showed the same trends as the chloride figures, except that, during the first sampling, the total soluble salt concentration in the type Y "scald" was not significantly higher at 0-1 in. than at 6 in. in the uneroded soil supporting the *Bassia* community.

TABLE 8

Chloride concentrations in samples collected October – November 1959.

(1) Geometric means (Cl as % NaCl) (2) Log_{10} (%NaCl × 10^3). Standard error = mean standard error for all depths at each sampling site.

Depth in inches	Between bushes type X	Under saltbush type X	Under bluebush type X	Between bushes type Y	Bare "scald" type X	Bare "scald" type Y	Grass Sand accumulation on type X
0–1	(1) 0·003 (2) 0·477	0·025 1·253	0·011 1·045	0·004 0·602	0·059 1·774	0·033 1·524	0·002 0·338
$5\frac{1}{2}$–$6\frac{1}{2}$	(1) 0·004 (2) 0·563	0·010 1·053	0·007 0·855	0·061 1·786	0·361 2·557	0·484 2·684	0·003 0·448
$11\frac{1}{2}$–$12\frac{1}{2}$	(1) 0·032 (2) 1·502	0·059 1·770	0·052 1·714	0·274 2·438	0·390 2·591	0·547 2·738	0·005 0·661
$17\frac{1}{2}$–$18\frac{1}{2}$	(1) 0·109 (2) 2·038	0·120 2·080	0·110 2·040	0·488 2·688	0·363 2·560	0·484 2·685	0·006 0·789
$23\frac{1}{2}$–$24\frac{1}{2}$	(1) 0·189 (2) 2·277	0·186 2·269	0·164 2·214	0·509 2·707	0·362 2·559	0·428 2·632	0·010 0·978
Standard error	±0·126	±0·126	±0·126	±0·055	±0·037	±0·130	±0·078

DISCUSSION

The concentration of chlorides and of total soluble salts was significantly higher in the topsoil directly under the saltbush and bluebush canopies than in the soils between the bushes. Furthermore, in the 0-1 in. soil sample, chlorides contributed between $\frac{1}{3}$ and $\frac{1}{2}$ of the total soluble salts under the canopies of the bushes, but only $\frac{1}{8}$ to $\frac{1}{10}$ of those in the soil between the bushes. This shows that there was an absolute increase in the amount of chlorides under the bushes. Thus uneven entry of rainfall into the soils, due to water being shed from the canopies or being lost by direct evaporation from droplets on the leaves, cannot have caused the formation of the pattern of chloride distribution. The observed pattern of chloride distribution must have developed after the bushes became established, because the zone of maximum chloride accumulation (depth 0-1 in.) occurred in the deposit of wind-blown sand that had been "trapped" by the bush canopies.

Apparently the chlorides that were concentrated in the topsoil under the bushes were absorbed from the subsoil under the bush canopies and from the soil between them. At the time of the first sampling the chloride concentration was (1) significantly higher at 0-1 in. under the saltbush canopies, (2) significantly lower under the saltbush canopies at depth of 18 and 24 in., and (3) significantly lower in the soil between the bushes at depths of 12, 18 and 24 in., than in the two later samplings.

During dry times saltbush and bluebush progressively shed their leaves, thereby reducing the amount of water lost through transpiration. The dead leaves accumulate under the canopies. It is proposed that the chlorides that had accumulated in the topsoil under the bush canopies were released from these fallen leaves. Saltbush leaves are known to have a high ash content with the ash consisting principally of sodium chloride (Wood 1925; Beadle, Whalley and Gibson 1957). From its effect on the soil salinity pattern it is inferred that bluebush, which like saltbush belongs to the family Chenopodiaceae, must also concentrate chlorides in its leaves. There was little difference in chloride concentration under the saltbush and bluebush. No comparisons can be made using the data from the first sampling because the soils under the two species were different. In the second sampling, chloride was significantly higher under saltbush than under bluebush at 0-1 in., but the third sampling showed no significant differences. During the second sampling the total soluble salt concentration was not higher under saltbush at 0-1 in.

Accumulation of chlorides would be advantageous to the bushes during times of moisture stress, for the growth of plants with a low chloride tolerance, such as the grasses, would be inhibited and competition for moisture reduced.

Apparently there is a progressive accumulation of chlorides in the topsoil under the bushes and decrease in the surrounding soil during dry periods. Prior to the first sampling time, which was characterized by maximum concentration of chlorides under the bushes and maximum depletion in the surrounding soil, little effective rainfall had fallen for 10 months. However, about 1·50 in. fell some $2\frac{1}{2}$ months prior to the second sampling and 0·62 in. about 6 weeks before the third one (Table 2). There were no significant differences between the second and third samplings in the chloride concentrations in any of the sites either "between bushes", under saltbush canopies or under bluebush canopies.

Saltbush and bluebush are not unique in their effects on the distribution of soil salts. Roberts (1950), and Fireman and Hayward (1952) have shown that several kinds of bushes that grow in semi-arid environments in the United States, concentrate salts in the soil under their canopies.

The analyses show that in the type X soil, the chloride concentration reached a maximum at 24 in. and then remained constant with depth. This indicates that there was no significant water movement in the soil below a depth of between 18 and 24 in. Jackson (1958) concluded that the maximum depth of rainwater penetration into similar soils at Yudnapinna Station, where the climate is similar, was also between 18 and 24 in.

A consideration of the rainfall in relation to the amount of water required to bring the soil to field capacity, 4 in. (see Table 3), also indicates that water would penetrate the type X profile to between 18 and 24 in. At the first sampling time the moisture content of type X soil was less than that held at a tension of 15 atmospheres, commonly referred to as the permanent wilting point of plants (Table 3). The top 18 in. contained just over 1 in. of water, so a fall of about 3 in. of rain would have been required to raise this depth of soil to field capacity. Table 3 also shows that the top 18 in. of the type Y soil holds about 4·75 in. of water at field capacity. At the first sampling time about 3·3 in. of rain would have been required to bring this depth to field capacity.

Single falls of rain as high as 3 in. are rarely received in the study area; during the 6 year period 1954-1959 falls of about 3 in. per *month* were only recorded on 3 occasions (Table 2). Once, in 1955, an exceptionally large amount of rain, 4·5 in., fell during February. Lack of penetration of water below 24 in. would explain why saltbush and bluebush roots do not penetrate below this depth, and is probably the reason for the absence of trees in this country.

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Statistical analyses of the chloride and total soluble salt figures were made by Messrs. K. Cellier and G. A. McIntyre, C.S.I.R.O., Division of Mathematical Statistics, and the former offered many helpful suggestions regarding the interpretation of the data. All of the chemical analyses were carried out in the laboratories of the C.S.I.R.O., Division of Soils, Canberra, under the direction of Mr. H. J. Beatty. A number of people assisted with field samplings at different times, notably Messrs. G. and S. Scholz formerly of Bimbowrie Station, and Mr. O. B. Williams, C.S.I.R.O., Division of Animal Physiology, Parramatta.

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A CONTRIBUTION TO THE MESOPHYTIC FLORA OF SOUTH AUSTRALIA

BY HEINZ AMTSBERG†

Summary

An introductory description of the macroflora of the Springfield Triassic Basin and the analysis of its age are given. The following palaeobotanical divisions are represented: Ginkgophyta, Arthrophyta, Pteridospermophyta, also Gymnospermous seeds and Incerae sedis.

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(Springfield and Leigh Creek)

by Heinz Amtsberg†

[Read 10 July 1969]

SUMMARY

An introductory description of the macroflora of the Springfield Triassic Basin and the analysis of its age are given. The following palaeobotanical divisions are represented: Ginkgophyta, Arthrophyta, Pteridospermophyta, also Gymnospermous seeds and Incertae sedis.

INTRODUCTION

In 1957 leaf impressions of Triassic age were found by students of the University of Adelaide under the leadership of Dr. Kleeman, approximately 46 km north of Quorn in the Flinders Ranges of South Australia. These impressions were identified by Ludbrook (1961) as *Dicroidium feistmanteli* (Johnston) and freshwater molluscs *Unio* and *Protovirgus* were described by Ludbrook from the same source. In 1958 and 1959 comprehensive drilling in search of coal was carried out at Springfield by the South Australian Department of Mines, but the project was abandoned as only thin seams of coal were discovered.

In 1965 the writer examined fossil plant specimens from Springfield lodged with the University of Adelaide, which prompted the present investigations.

METHOD

The Springfield Triassic Basin (Lat. 37° 07′ S, Long. 138° 25′ E) is situated some 375 km north of Adelaide in an undulating section of the Flinders Ranges, bordering the Willochra plain.* The roads from Adelaide are bituminized, with the exception of the last 15 km which are bush tracks. Due to some hazardous creek beds in the latter section, the locality should be visited during the dry season, using a four-wheel-drive vehicle.

The specimens, unless specifically stated otherwise, were collected by the writer during the years 1965 to 1969, on the central mesa of the Springfield Basin, Section 48 Hundred of Cudla Mudla. They were picked up from the surface, or dug out from a depth of up to 20 cm. Where a specimen is mentioned with its counterpart, the original rock was split open by the writer on the site.

Descriptions are based on hand lens observations, microscopic investigations have not been carried out.

All described specimens have been listed and deposited with The South Australian Museum, Adelaide. The numbers with the prefix P, shown in brackets in the text, are the Museum registration numbers.

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* For locality map see *Trans. R. Soc. S. Aust.* 84: 140, for geological map see Willochra Geological Survey sheet, Department of Mines, Adelaide.

Division Ginkgophyta

Family GINKGOACEAE

Ginkgo antarctica (Saporta)

(Plate 1, figs. 1-2)

Fig. 1 Hypotype (P14117)

Description: Portion of a *Ginkgo* leaf, only partly preserved. The centre part of the lamina has been preserved, the outer margin is missing. The base of the lamina has been laying exposed and has weathered. The width of the upper part of the lamina is 40 mm, the width of the lower part 8 mm. The available length is 18 mm, the length of the full lamina is estimated at 30-40 mm (without petiole). The lamina is split into four lanceolate segments, curved outwards. The segments are of different width, average width at the centre line is 5-10 mm. The veins are clearly marked, dichotomously branching, and 1 mm apart.

Fig. 2 Hypotype (P14118)

Description: A small *Ginkgo* leaf, lamina only (spur shoot leaf?). The lamina is triangular in shape, width at the margin 25 mm, length 30 mm. Slightly off centre to the right is a pinnule (*Dicroidium*) overlying the margin. Slightly off centre to the left of the margin the lamina is lobed (torn?), the width of the lobe at the margin is 2½ mm, the depth 4 mm. The lobe appears to have been torn during the embedding process. The outer margin at the left side appears to be damaged. The lamina near the base is partly covered with the overlying material. A petiole cannot be distinguished. The veins in the lamina are numerous, radially arranged, and repeatedly branch dichotomously. They are scarcely visible to the naked eye. Four veins are located in the width of 1 mm. The imprint of the veins is clear toward the margin, however it fades out near the base through imperfect impression.

Division Arthrophyta

Class Equisetales

(Plate 1, figs. 3-7)

The findings so far are only fragmentary, but there is enough evidence to claim that this class was present. The details, however, are insufficient to put the plants into a particular genus or species, as only parts of stems have been found and no trace of complete leaves. Leaf fragments which could be assigned to Equisetales differ from those described from other Triassic localities.

Fig. 3 (P14119)

Stem only, length of impression 68 mm, width 20 mm. The stem shows 5 longitudinal flattened ridges. Nodes and striation are not visible.

Fig. 4 (P14120)

Stem with one node, length 63 mm, width 16 mm, width at the node 18 mm. The impression is flattened and at the top end the diameter is 1 mm. The stem appears to be loose from the surrounding bed. It is distinctly striate, showing 7 faintly distinguishable longitudinal ridges, bulging out at the node, which is partly damaged, so that the base of the leaf sheath is not visible.

Fig. 5 (P14121)

Faint impressions with one node. Length 45 mm, width 8-10 mm. The node is located at approximately the centre of the stem. 7 longitudinal ridges are faintly visible.

Fig. 6 (P14122)

Stem with two nodes. Length 30 mm, width 9 mm. The internode is 15 mm long. The stem appears to be twisted into an angle of 30°. The imprint is distinctly ribbed, the ribs running parallel, occasionally branching dichotomously. 22 ribs are located on the stem.

Fig. 7 (P14146)

Stem with two nodes and three internodes, length 40 mm, width 7 mm. The internodes are 14 mm long. Five ribs are distinguishable on the centre internode. The specimen shows five leaf scars at the nodes, each ½ mm in diameter.

Division Pteridospermophyta

Family CORYSTOSPERMACEAE Thomas 1933

Genus Dicroidium Gothan 1914

Dicroidium odontopteroides (Morris) Gothan

(Plate 1, fig. 8; plate 3, figs. 16 and 17)

In the description of the following specimens the name *D. odontopteroides* has been used in a broad sense to include plant remains whose taxonomy cannot be better clarified due to imperfect preservation.

Plate 1, fig. 8 (P14123)

Partly preserved lamina of a frond, with a well preserved cuticle on the rachis and on part of the pinnules. Imprint of a frond with the rachis forked dichotomously. Full length of the rachis 68 mm, width near the base 1½ mm, width near dichotomy 2 mm. Width of the rachis above the forking 1 mm, length of the rachis unforked 43 mm. The rachis is covered with an uneven surface created by raised blisters, 30 blisters in the length of 10 mm. The pinnules are located on both sides of the rachis, at a close set. The shape varies from lanceolate obtuse, to semicircular. All pinnules are attached to the base in full width. The venation is odontopteroid, some pinnules show a centre vein, the latter following half way through the pinnule. Certain secondary veins branch dichotomously approximately half way to the margin.

Plate 3, fig. 16 (P14131)

Description: Imprint of a fernlike dichotomous frond, length 80 mm. The two pinnae branch at an acute angle 25 mm from the basal end of the frond. The pinnules are located at a close set and are attached to the base in full width. Their margin is entire, the shape varies from elongate with an ovate apex, to semicircular. The elongate pinnules are located toward the apices of the pinnae. They possess a midrib which extends 2/3 of the way toward the margin before it opens out. The secondary veins form an acute angle with the midrib. The semicircular pinnules are dominant near the base of the frond and at the inner side of the pinnae toward the dichotomy, the venation is odontopteroid. Length of pinnules 4-9 mm. The secondary veins show dichotomous branching.

Remarks: This specimen resembles the Queensland specimen described by Walkom (1917) under *D. lancifolia.*

Plate 3, fig. 17 (P14132)

Description: Part of frond with a seed-like structure attached to the rachis (poorly preserved). Several secondary branches arise from the main rachis, their length being partly obscured, but at least 22 mm. The visible length of the rachis is 90 mm, width at the base 2 mm, width near the apex 1 mm. The rachis bends

slightly into an arc. Pinnules are born on the secondary branches, and also on the main rachis, their venation is odontopteroid, but only faintly visible. A seedlike structure arises 55 mm from the base on the main rachis. The structure is pear-shaped, its surface is somewhat coarser than the underlying grey argillite. It appears to possess a short pedicel and to arise in the angle between the main rachis and a secondary branch. The seed(?) is raised 2 mm above the underlying material. (On the counterpart it creates a respectively deep imprint.) The full length of the seed is 13 mm, width of the widest part near the apex 7 mm. The pedicel of the seedlike structure appears to continue as a 1 mm wide ridge almost to the apex of the seed.

Division Pteridospermophyta

Family CORYSTOSPERMACEAE Thomas 1933

Genus Dicroidium Gothan 1914

Dicroidium feistmanteli (Johnston) 1895 Gothan 1914

(Plate 2, figs. 9-11)

Remarks: This genus, which gives the name to an epoch of the Mesozoic flora, has been described by many authors, and occurs in several places of the Gondwanaland area. In the descriptions, the recommendation of Walkom (1915-1919) has been adopted, thus the species is defined as follows:

Description: Frond bipinnate, venation odontopteroid.

Material:

	Hypotype No. (P14124) Fig. 9	Hypotype No. (P14125) Fig. 10	Hypotype No. (P14126) Fig. 11
Fragments:	1	1	3
length:	60 mm	approx. 115 mm	70 mm
width:	40 mm	180 mm	50 mm
Width of rachis (widest part near base):	2 mm	5 mm	2 mm
Pinnules			
width:	5 mm	7 mm	3 mm
length:	6 mm	10 mm	5 mm
Shape of pinnules:	semicircular to narrow elongate	semicircular	semicircular to narrow elongate
Attachment of pinnules to base:	full width	full width	full width
Angle of pinnules to rachis:	90°	90°	45°-90°

Division Pteridospermophyta

Family CORYSTOSPERMACEAE Thomas 1933

Genus Dicroidium Gothan 1914

Dicroidium acuta (Walkom) 1917

(Plate 2, fig. 12)

Description: The part of a frond is 40 mm in length, and divides dichotomously into two pinnae at about the middle of the impression. The rachis is 2 mm wide at the base, and is striate in places. The pinnules are spaced about 1½ mm apart, are 11 mm long, 3 mm wide at the base, tapering into an acute tip, and are attached by the whole base, joined by a narrow lamina along the rachis. The venation is alethopteroid. The secondary veins make an angle of about 30° to the midrib, which persists to the tip.

Material: The original is specimen No. F 332 in the Queensland Geological Survey Collection, and was found in the Ipswich Series in Queensland (Walkom 1917).

Hypotype (P14127) fig. 12 appears to be similar in all aspects to the original specimen.

Division Pteridospermophyta

Family CORYSTOSPERMACEAE

Genus Xylopteris (Carruthers) 1872 Frenguelli 1943

Xylopteris elongata (Carruthers) 1903

(Plate 2, figs. 13-15)

Description: The available length of the frond is 50 mm. The dichotomous branching starts 15 mm from the basal end. The width of the branches is 1·5 mm. The width of the pinnae is 1 mm, their length is somewhat obscure, however, a minimum of 25 mm is visible. The strong single medium vein on all parts on the imprint is distinct.

Material: Hypotype (P14128) fig. 13.

Hypotypes (P14129) fig. 14 and (P14130) fig. 15.

Gymnospermous seeds

(Plate 3, figs. 18-21)

Fig. 18 (P14133)

Fig. 19 (P14134)

Fig. 20 (P14135)

Fig. 21 (P14136) This specimen was found in close proximity to the impressions of *Dicroidium feistmanteli* (Johnston), in the overburden at the coalfields of Leigh Creek in December 1967.

Division Ginkgophyta

Family GINKGOACEAE (?)

Genus Psygmophyllum Schimper 1870

Psygmophyllum cf. etheridgei Arber

(Plate 4, figs. 22-24)

Several specimens have been collected by the writer at the Leigh Creek Coalfield, thus showing the abundance of the genus *Psygmophyllum* at the locality. The fragments described give an indication of the size of the lamina of the plants bearing these leaves.

All specimens were collected in December 1967 from the overburden of the Telford Open Cut (Leigh Creek Coalfield).

Fig. 22 (P14137)

The imperfect imprint of the lamina is 14 cm in length, its greatest width is 9 cm. The full length of the lamina is estimated at 19-20 cm. The veins are 1 mm apart. The distal end and the base of the lamina are not preserved.

Fig. 23 (P14138)

Part of a lamina, size: 70 mm x 45 mm. The veins are 1 mm apart and branch dichotomously. The apex of the lamina appears to be torn.

Fig. 24 (P14139)

Part of a lamina, length 12 cm, visible width 4 cm. The parallel veins are clearly marked, 1 mm apart, and show dichotomous branching.

Family INCERTAE SEDIS
Genus TAENIOPTERIS Brongniart 1828
Taeniopteris cf. dunstani Walkom 1917

(Plate 4, figs. 25-26)

Fig. 25 (P14140), fig. 26 (P14141)

Description: Part of frond upper surface. The impression appears to be the part near the apex. It measures 28 mm in length. The average width is 12 mm. The apex appears to be acute, the width near the apex is 7 mm. A strong midrib is visible. The veins are simple and arise at an angle of approximately 70° from the midrib, sometimes they are forked, and occasionally two adjacent veins join before reaching the margin. About 22 veins are located in a distance of 1 cm. A marginal vein is visible.

Family INCERTAE SEDIS
Genus TAENIOPTERIS Brongniart 1828
Taeniopteris spatulata McClelland 1850

(Plate 4, figs. 27-30)

Fig. 28

Description: Part of frond, narrow, slightly lanceolate, the length is 80 mm. The base and distal end are missing, the total length of the frond is unknown. The midrib is prominent and longitudinally striate, its width is 1 mm. The width of the frond at the basal end is 8 mm, at the distal end 9 mm. The veins branch from the midrib at approximately right angle, occasionally they branch anywhere between midrib and margin. There are 10-12 veins located in a length of 5 mm.

Material: Hypotypes (P14142) fig. 28, (P14143) fig. 27, (P14144) fig. 29, (P14145) fig. 30.

CONCLUSION

Ludbrook (1961) does not give the epoch of the Triassic Basin of Springfield, while Brown, Campbell, and Crook (1968) ascribe it to (?)Lower Triassic. The analysis of its macroflora suggests that these deposits were laid down during approximately the Upper Triassic age.

Du Toit (1954) remarks that the *Thinnfeldia* (*Dicroidium*) flora is typical of the Upper Triassic (Rhaetic) in the Cape Natal region (South Africa), and that these Molteno beds have a surprising similarity to the Upper Triassic flora of Ipswich (Queensland), and to the Rhaetic flora of India, Argentina, New South Wales and Tasmania. This similarity is present also in the macrofossils collected from the Springfield Triassic Basin described in this paper. The genus *Ginkgo* has been recorded from the Upper Triassic in the Ipswich series (Walkom 1917). *Taeniopteris* and *Xylopteris* are considered to be Upper Triassic (Seward 1963, Walkom 1917-1919), while Townrow (1967) considers *Dicroidium* and *Xylopteris* to be Middle to Upper Triassic.

The descriptions of the macrofossils of Leigh Creek, based on the "Sweet" collection revised in 1926 by Chapman and Cookson, also show a resemblance to the Springfield fossils.

The Springfield flora is an impoverished fragment of the floras from the localities mentioned above. It does not offer any new information on which the dating of these floras can be improved, but its similarity to them shows that they are of about the same age, that is approximately Upper Triassic.

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATES

Plate 1.

Fig. 1 *Ginkgo antarctica* Hypotype (P14117) x 1·5.
Fig. 2 *Ginkgo antarctica* (spur shoot leaf?) Hypotype (P14118) x 1·5.
Fig. 3 Equisetales stem showing 5 longitudinal flattened ridges. (P14119) x 1.
Fig. 4 Equisetales stem with one node. (P14120) x 1.
Fig. 5 Equisetales stem with one node. (P14121) x 1·5.
Fig. 6 Equisetales stem with two nodes. (P14122) x 2.
Fig. 7 Equisetales stem showing leaf scars at the nodes. (P14146) x 1·5.
Fig. 8 *Dicroidium odontopteroides* showing raised blisters on the rachis. (P14123) x 1.

Plate 2.

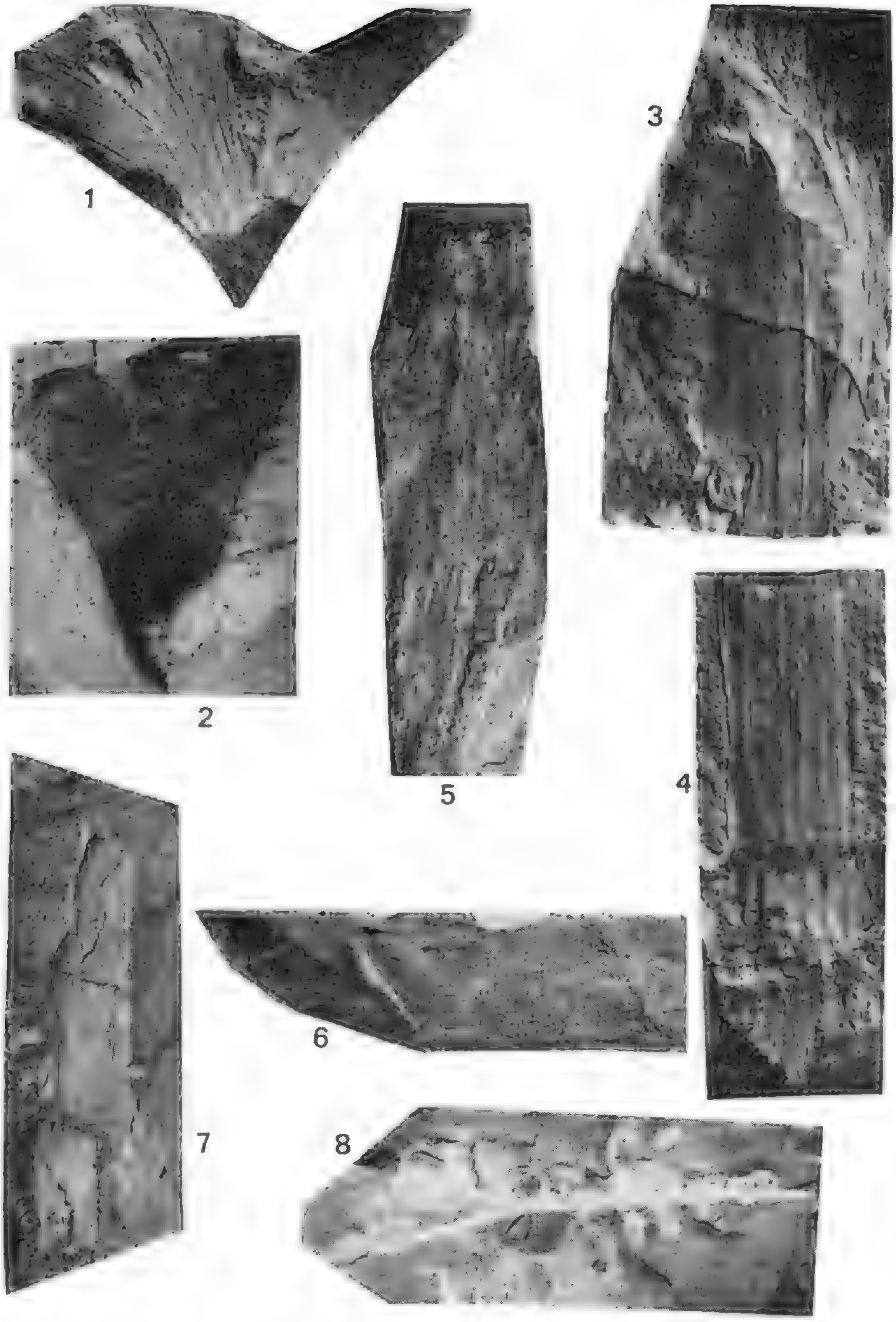
Fig. 9 *Dicroidium feistmanteli* Hypotype (P14124) x 1.
Fig. 10 *Dicroidium feistmanteli* showing large frond. Hypotype (P14125) x 0·25.
Fig. 11 *Dicroidium feistmanteli* Hypotype (P14126) x 0·5.
Fig. 12 *Dicroidium acuta* Hypotype (P14127) x 2.
Fig. 13 *Xylopteris elongata* Hypotype (P14128) x 1.
Fig. 14 *Xylopteris elongata* Hypotype (P14129) x 1.
Fig. 15 *Xylopteris elongata* Hypotype (P14130) x 1.

Plate 3.

Fig. 16 *Dicroidium odontopteroides* (P14131) x 1.
Fig. 17 *Dicroidium odontopteroides* with seed-like structure attached to the rachis. (P14132) x 0·8.
Fig. 18 Gymnospermous seed (P14133) x 1.
Fig. 19 Gymnospermous seed with pedicel (P14134) x 2.
Fig. 20 Gymnospermous seed (P14135) x 1·5.
Fig. 21 Gymnospermous seeds from Leigh Creek (P14136) x 1.

Plate 4.

Fig. 22 *Psygmophyllum cf. etheridgei* (P14137) x 0·5.
Fig. 23 *Psygmophyllum cf. etheridgei* showing the torn apex of the lamina. (P14138) x 1.
Fig. 24 *Psygmophyllum cf. etheridgei* (P14139) x 0·75.
Fig. 25 *Taeniopteris cf. dunstani* (P14140) x 2.
Fig. 26 *Taeniopteris cf. dunstani* (P14141) x 2.
Fig. 27 *Taeniopteris spatulata* Hypotype (P14143) x 1.
Fig. 28 *Taeniopteris spatulata* Hypotype (P14142) x 1.
Fig. 29 *Taeniopteris spatulata* Hypotype (P14144) x 1.
Fig. 30 *Taeniopteris spatulata* Hypotype (P14145) x 0·5.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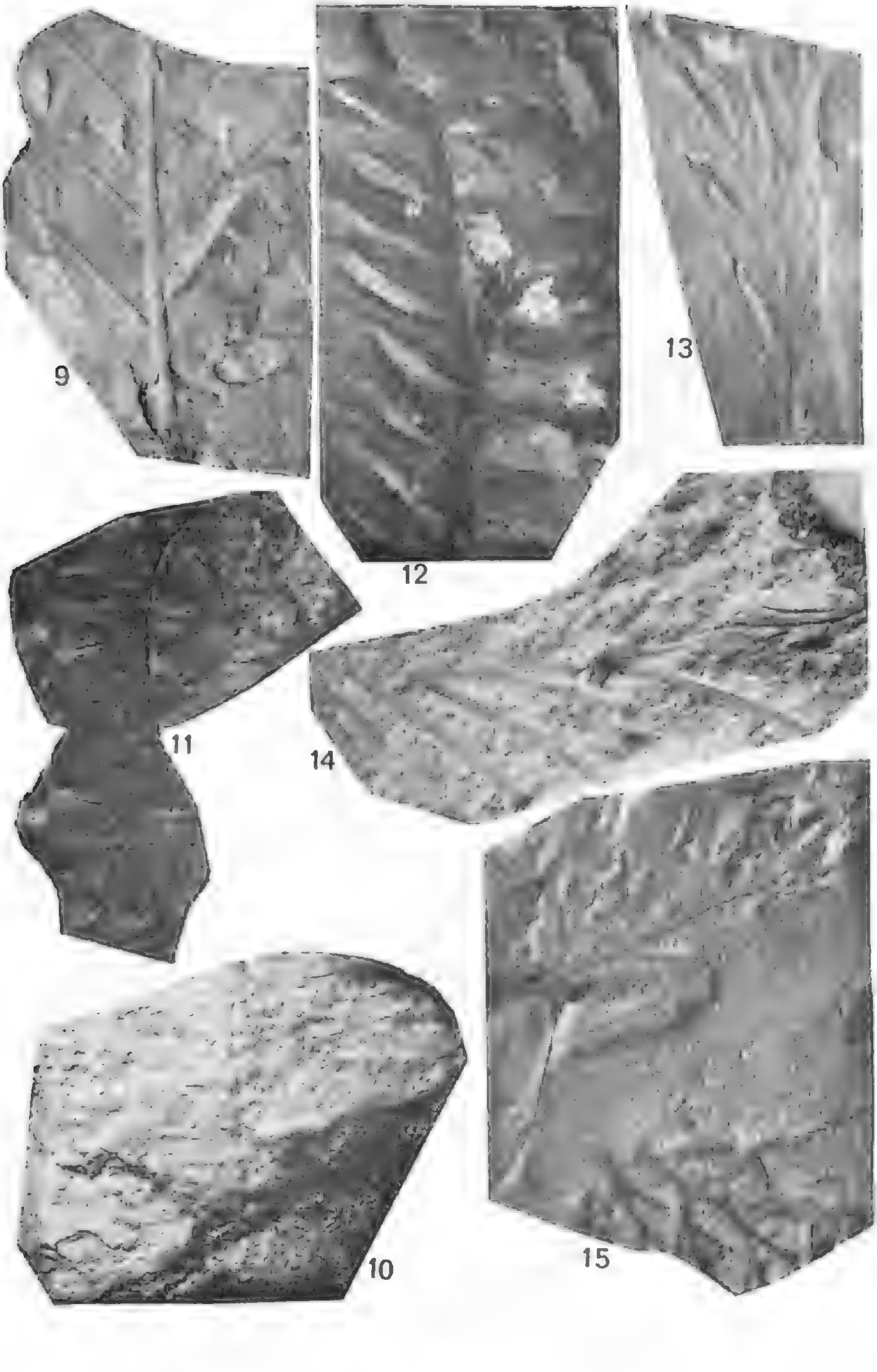
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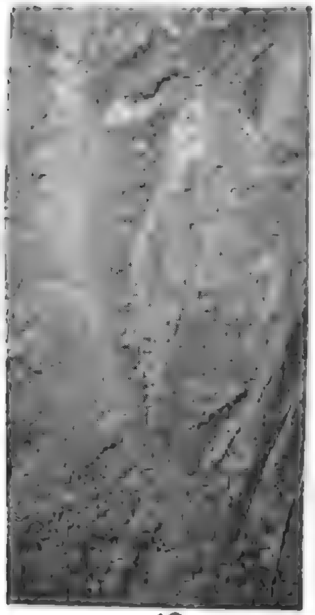
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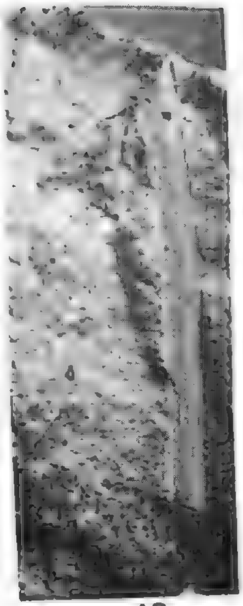
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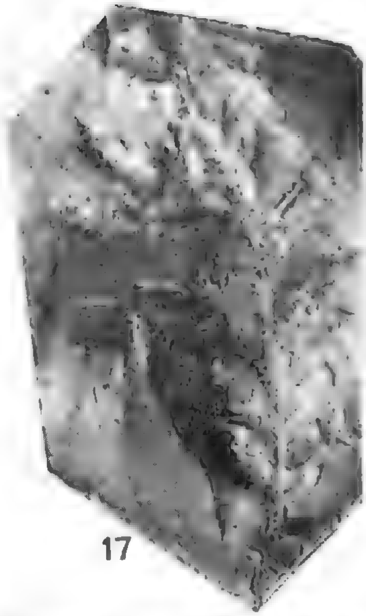
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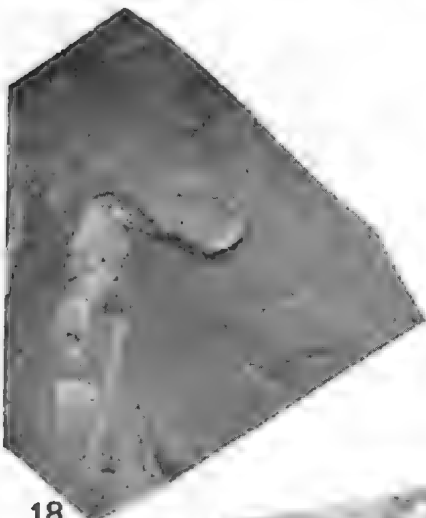
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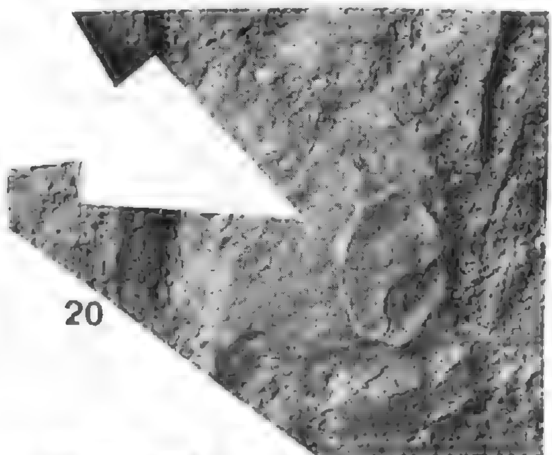
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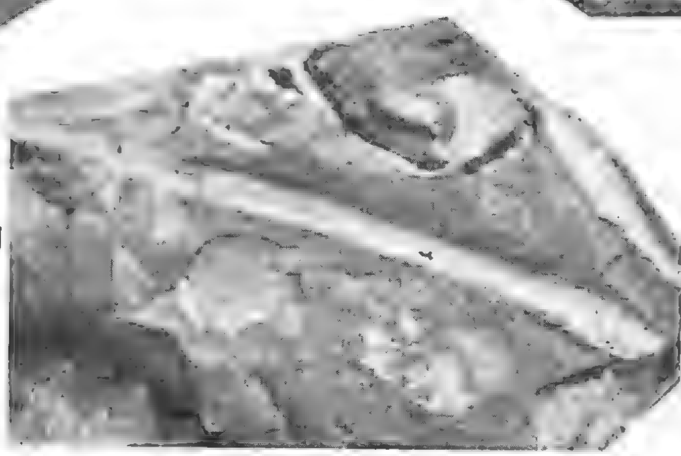
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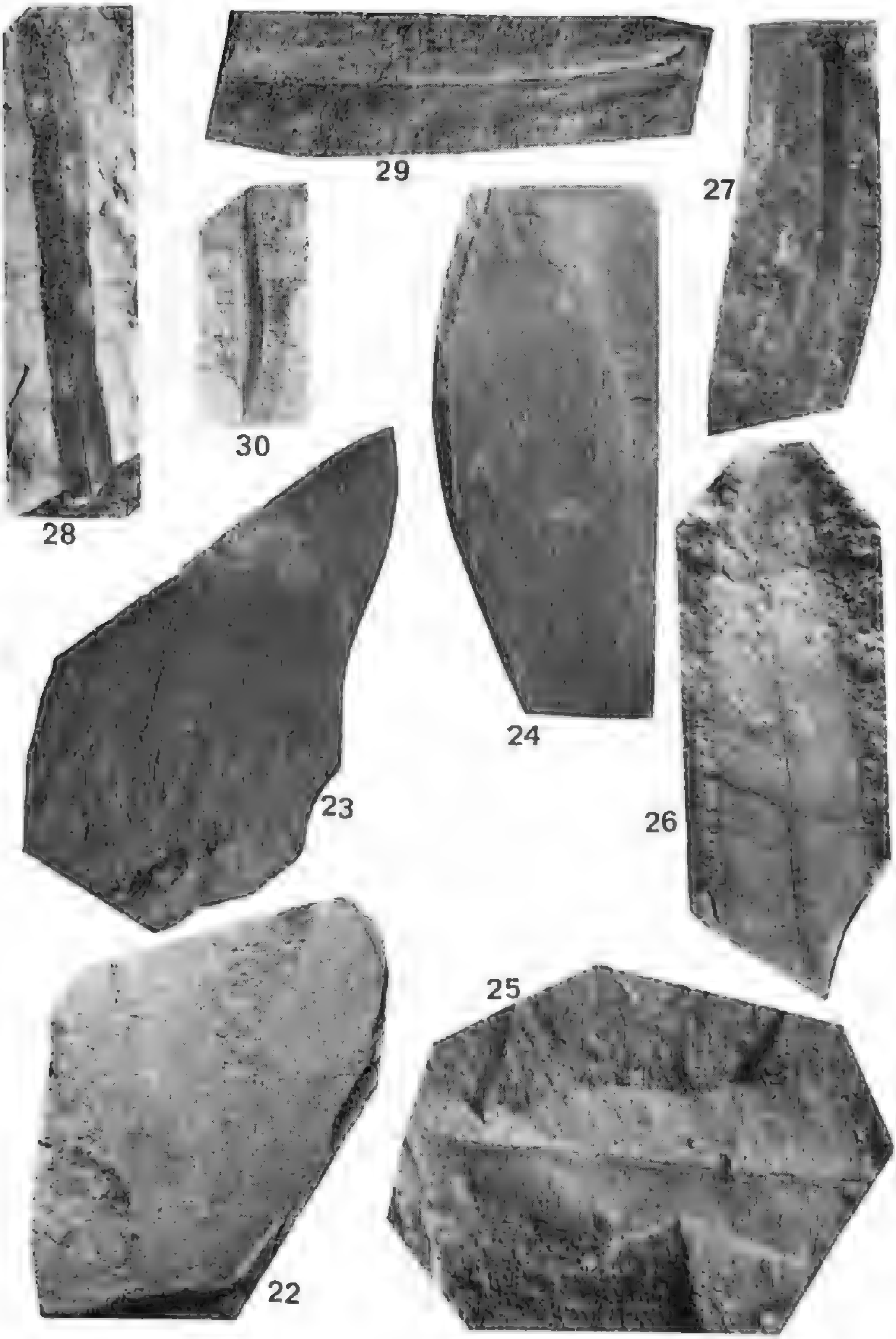
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REVISION OF THE *ACAENA OVINA* A. CUNN. (ROSACEAE) COMPLEX IN AUSTRALIA

*BY A. E. ORCHARD**

Summary

The species until now known as *A. ovina* is here divided into four on the basis of indumentum, leaf and fruit characters, supported to some extent by geographical distribution. Two names, *A. echinata* Nees and *A. agnipila* Gdgr., are reinstated, one new species (A. X *anserovina*) is described, three varieties occur in new combinations and five varieties are newly described. The nomenclatural history and the occurrence of hybridization within the *A. ovina* group are discussed, and an hypothesis concerning the origins of the taxa is advanced. A key to the Australian species of *Acaena* includes the infraspecific taxa recognized in the *A. ovina* complex.

Only a selection of the specimens examined from the following herbaria is cited: Adelaide (AD, ADW); Bremen (BREM); Brisbane (BRI); Firenze (FI); Geneve (G); Halle (HAL); Lyon (LY); Melbourne (MEL); Sydney (NSW); Perth (PERTH); Wien (W).

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[Read 11 September 1969]

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NOMENCLATURAL HISTORY

The first description of an *Acaena* from Australia was by J. R. and J. G. A. Forster in 1776 in their "Characteres Generum Plantarum" under the name *Ancistrum anserinaefolium.* This is now known as *Acaena anserinifolia* (Forst. et Forst. f.) Druce.

Acaena ovina was described by Allan Cunningham in 1825 in Barron Field's "Geographical Memoirs of New South Wales by Various Hands". His description read,

"Incano-hirsuta, foliolis profunde incisus pinnatifidis; laciniis oblongis, spicis oblongis; inferioribus remotifloris, caule reclinato subdemerso.

Frequent on moist lands, Bathurst, etc."

In 1844 Nees in Lehmann's Plantae Preissianae described another species, *Acaena echinata* from "In rupestribus umbrosis ad latus orientale montis Brown (York) d. 4 Sept., 1839 Herb. Preiss. No. 2395". The distinctive features of this species were supposed to be the unequal conical spines lacking barbs (. . . "spinis calycis conicus inaequalibus simplicibus (haud uncinatus)").

Schlechtendal in 1847 described another new species, *Acaena behriana*, which in part read, " . . . flores decandri, . . . calyx extus spinis magnitudine variis rigidis basi latioribus apice glochidiatis instructus".

J. D. Hooker, in Flora Tasmaniae (1856) reduced *A. behriana* Schldl. and *A. echinata* Nees to synonyms of *A. ovina* A. Cunn. This judgement was followed by Bentham in Flora Australiensis (1864) who also added Hooker's *Acaena montevidensis* to the synonymy of *A. ovina*. *A. montevidensis* was subsequently also declared synonymous with *Acaena eupatoria*, another South American species described 10 years earlier in 1827 by Chamisso et Schlechtendal. *A. eupatoria* had a 4 partite calyx, 2 stamens, 2 styles and a 2 seeded fruit.

Citerne (1897) attempted to distinguish *A. ovina* from *A. eupatoria* by their stamens, claiming that *A. ovina* had exserted stamens, while in *A. eupatoria* the stamens were enclosed by the sepals. Bitter (1911) pointed out that one form of

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A. ovina which he named subsp. *calviscapa* also had short filaments so that the anthers did not exceed the sepals. In addition, some specimens in cultivation in botanic gardens and referred by him to his subsp. *maxima* also had stamens scarcely exceeding the sepals, while in the species considered by him to be most closely related to *A. eupatoria*, viz. *A. polycarpa* Griseb. he recognised two varieties, var. *brevifilamentosa* and var. *longifilamentosa*. On the other hand, Bitter based the description of *A. ovina* subsp. *calviscapa* on material bearing only immature fruits. Present observations show that the length of the filament increases markedly with age, so that the short filaments in the subspecies may be a result of the stage of development of the material examined.

Bitter examined the type of *A. eupatoria* and confirmed that the number of stamens was two, and that in this and in all other specimens of it, the stamens were enclosed in the sepals. Only very rarely is the number of stamens in *A. ovina* s.l. as low as two, indicating that the relative lengths and numbers of stamens may be useful in separating the two species.

Only one specimen of *A. eupatoria* was available for comparison in the present study, but in this specimen, as in all available figures and descriptions, the stipules were deeply cut (4-fid in this specimen, 2-3-fid in some written accounts), while *A. ovina* s.l. always has entire lanceolate or triangular stipules. This, in addition to the differences in stamen number and size mentioned earlier and the geographical separation seem sufficient to keep *A. eupatoria* Cham. et Schldl. (syn. *A. montevidensis* Hook. f.) distinct from the Australian species.

Bitter was unable to comment on the status of *A. behriana* and *A. echinata* as he did not see the type specimens. He suggested that *A. echinata* might prove to be a variety of *A. ovina* but the only specimens that he saw in which the spines lacked barbs (the main distinguishing character in the original description) and which he named *A. ovina* subsp. *capitulata* did not match *A. echinata* in habit in his opinion. An isotype of *A. echinata* in the National Herbarium of Victoria (ex Herb. Sonder, MEL 21944) unfortunately has most of the spike missing, and only one incomplete fruit remains.

It appears that the spines were unequal in this fruit, the longer ones having thickened conical bases. Whether or not these spines were barbed cannot be determined as they are all broken off just above the base. The very small spines are still undamaged and unbarbed, but this is often the case even in fruits where the larger spines are barbed. In all the specimens examined, only one (L. A. S. Johnson, NSW 15052), has barbless spines and the character seems to be of little significance.

The important characters in the description of *A. behriana* appear to be the ten stamened flowers with filaments fused at the base. Bitter saw no plant which fitted this description and retained the name as a synonym. Fusion of the filaments at the base is usual in the whole *A. ovina* complex, although misunderstood by J. D. Hooker (1856) as "a very short lobed or toothed epigynous disc" in "female" flowers in which the filaments had apparently broken off. In no specimens have flowers with as many as 10 stamens been seen, the maximum number being seven and this occurs only rarely. The usual number is 5 with sometimes (2?), 3, 4 or 6.

The type sheet of *A. behriana* in Halle consists of four elements falling into three groups. Two of them are sterile (one has part of an inflorescence stalk but no flowers or fruits) and from their densely pubescent nature probably belong to the species here called *A. agnipila*. The third consists only of an inflorescence bearing semi-mature fruit. The fruits are hairy with unequal conical based spines, thus placing this plant in *A. echinata* var. *retrorsumpilosa*. The fourth plant is here chosen as the lectotype of *A. behriana*. It bears about 6 leaves and an infructescence

to which 2 mature fruits still cling. An isotype of *A. behriana* exists in the National Herbarium of Victoria (ex Herb. Sonder, MEL 21939), bearing a label in Schlechtendal's handwriting. It consists of a whole plant with an inflorescence in the bud stage. The flowers have 5 stamens not 10 as described by Schlechtendal.

Bitter (1911) divided *A. ovina* into 5 subspecies and 4 varieties on the basis of characters like fruit and spine indumentum, plant size, number of spines per fruit and number of leaflets per leaf, but provided no key. All except one of his types have been re-examined (the type of subsp. *nanella* formerly in Berlin is now lost) and many of his varietal epithets have been retained but in new combinations. The present system, however, cuts across that of Bitter, whose work was based on a very small number of collections.

Gandoger (1912) described 4 new species of *Acaena* from Australia. One of these, *A. dumulosa*, belongs in the *A. anserinifolia* complex and may or may not be distinct at the species level. A second, *A. tasmanica* is a later homonym of *A. tasmanica* Bitter, and both are possibly taxonomically synonymous with *A. montana* Hook. f., but a study of more material and the types will be necessary to determine this. Of the other two species, one (*A. pennatula*) can be matched with Bitter's *A. ovina* var. *subglabricalyx* which is here transferred to *A. echinata*, the other (*A. agnipila*) is distinct and is here maintained at specific rank.

KEY TO THE AUSTRALIAN SPECIES AND VARIETIES OF *ACAENA*

1. Flowers and fruits all arranged in a globular terminal head. Fruits 4 angled with 4 slender subequal spines, 1 at the apex of each angle. Stamens 2, cream. Creeping plants with long epigeal stolons.
   2. Calyx lobes persistent in fruit ± fused at the base, spines long (1-2 cm) in fruit, fruiting head 2-3 cm diam. .... *A. anserinifolia* complex
   2. Calyx lobes deciduous in fruit, free at the base, spines short (1-3 mm) in fruit, fruiting head under 1 cm diam. .... *A. montana*
1. Flowers and fruits not in a head as above. Stamens 2-8, purple. Plants lacking (except occasionally in *A.* × *anserovina*) long stolons, forming tight clonal clumps.
   3. Fruits in globular heads with 3 or 4 fruits scattered on stem below, ± 4 angled or globular, 4-6 slender spines at the apex, and several smaller ones on the body of the fruit. .... 4. *A.* × *anserovina*
   3. Fruits in elongate interrupted cylindrical spikes, ovoid or with 3-4 longitudinal angles. Spines many, equal or unequal, scattered over the entire fruit. (*A. ovina* complex.)
      4. Leaflets densely and evenly appressed pilose on the under surface, moderately appressed pilose on the upper surface; fruit ovoid, ± wrinkled, but in any case lacking longitudinal ridges formed by concrescence of thickened spine bases, spines slender.
         5. Spines of fruit unequal, 3-6 longer than the rest. .... 3. *A. ovina*
            6. Body of fruit and spines glabrous. .... var. *ovina*
            6. Body of fruit densely spreading pilose, spines ± pilose at extreme base. .... var. *velutina*
         5. Spines of fruit ± equal. .... 1. *A. agnipila*
            7. Fruit densely spreading pilose, spines glabrous, or pilose at extreme base only.
               8. Stamens (5-) 6 (-7), length 2·5-3·5 mm, stipules 4·0-5·0 (-8·0) mm, spike ± branched at the base. .... var. *agnipila*
               8. Stamens (3-) 4-5, length 1·5-2·0 mm, stipules 1·0-3·0 mm long, spike unbranched. .... var. *tenuispica*
            7. Fruit and spines glabrous.
               9. Stamens 3-4 (-5), length 1·5-2·0 mm, stipules 2·0-3·5 mm long. .... var. *aequispina*
               9. Stamens (5-) 6 (-7), length 4·0 mm, stipules 4·0-5·0 mm long. .... var. *protenta*
      4. Leaflets with hairs confined to the major veins and/or midrib on the lower surface, glabrous or ± sparsely pilose on the upper surface; fruit ovoid with all spines slender or with 3-4 longitudinal ridges formed by concrescence of the thickened bases of the 3-8 largest spines; spines always unequal. .... 2. *A. echinata* Nees
         10. Fruit and spines glabrous, largest spines with thickened bases.

11. Stamens (2-) 4-5, length 1·5-2·0 mm, stipules 1·5-2·5 mm long. var. *echinata*

11. Stamens 6-8, length 3·5-4·0 mm, stipules 3·0-5·0 mm long. var. *robusta*

10. Fruit spreading pilose, larger spines with thickened bases or slender.

12. Spines all slender, fruit ovoid without longitudinal ridges. var. *subglabricalyx*

12. Spines (at least the longest ones) with thickened bases, fruit with 3-4 longitudinal ridges.

13. Stamens (2-3-) 4-5, length 1·0-2·0 mm, stipules 2·0-3·0 mm long, spike unbranched. var. *retrorsumpulosa*

13. Stamens (4-)6, length 3·0-5·0 mm, stipules 4·0-5·0 mm long, spike usually branched at base. var. *tylacantha*

1. **Acaena agnipila** Gandoger, Bull. Soc. Bot. France 59 (1912) 706. [Typus: "Australia, in Sunny Corner. (Boorman)". Holotypus: LY ! isotypus: NSW (95900)!].
Figures: Bailey, Weeds Qld. (1906) fig. 87 (as *A. ovina*); N.S.W. Dept. Agric. (Whittet), Weeds (1962) pl. 80 (as *A. ovina*). *A. ovina* auct. non A. Cunn. in Field, Geog. Mem. of N.S. Wales (1825) 358: Bailey, Weeds Qld. (1906) 49 p.p.; Black, Fl. S. Aust. ed. 1.2 (1924) 266 p.p., ed. 2.2 (1948) 398 p.p.; Whittet, Weeds (1962) 345 p.p.

Syn. *A. ovina* subsp. *nanella* Bitter. Bibl. Bot. 74 (1911) 71. [Typus: "Novae Zealandiae insula meridionalis: Canterbury Plains, old river-bed of Waimakariri, 'Not native of New Zealand?' leg. L. Cockayne, herb. Berol." Holotypus: Non vidi, probably destroyed.]

Herbaceous perennial 20-50 (-66) cm tall, stems erect or ascending more or less densely pilose with spreading hairs; the leaves narrowly obovate to oblanceate, imparipinnate, petiolate, stipulate (3·5-) 8-15 (-22) cm long, petiole and rachis pilose with hairs as for the stems, stipule shape variable, always simple never multifid (1·0-) 2·0-5·0 (-8·0) mm long and 1·0-3·0 mm wide, glabrous or sparsely appressed pilose adaxially, more densely pubescent abaxially. Leaflets (9-) 17-23 (-27) per leaf, more or less sessile, ovate to oblong, serrate with (9-) 12-15 (-18) serrations of depth ½-⅔ of the lamina, (5-) 8-15 (-26) mm long and (3-) 6-9 (-13) mm wide, moderately appressed pilose on the upper surface, densely appressed pilose over the entire lower surface. Sepals 5, sparsely to densely appressed pilose externally 1·5-2·5 mm long and (0·5-) 1·0-2·0 mm wide; (3-) 4-5 (-7) stamens 1·0-4·0 mm long; 1(-2) styles 1·0-2·0 mm long. Fruit ovoid, glabrous or pubescent, spines all more or less equal, slender, glabrous, (15-) 30-40 (-55) all 1·0-2·0 (-3·0) mm long, barbed at the tip.

Distribution: S.E. Queensland, eastern New South Wales, eastern and central Victoria, the Mount Lofty Range in South Australia and Tasmania including Flinders Island. One specimen is known from each of North Island New Zealand and the Stirling Range in S.W. Western Australia, both probably recent introductions.

1A. var. **agnipila**.

Plant 30-45 (-60) cm tall, leaves (8-) 10-15 cm long, stipules linear to triangular 4·0-5·0 (-8·0) mm long and 1·5 to 2·5 mm wide, glabrous or sparsely pilose adaxially, densely appressed pilose abaxially. Leaflets (15-) 17-23 per leaf with 11-14 (-18) serrations, $\frac{1}{2}$-$\frac{2}{3}$ of the lamina width, (8-) 10-15 (-18) mm long and (5-) 7-9 mm wide. Spike often branched near the base; sepals 5, moderately pilose, 1·5-2·0 (-3·0) mm long and (0·7-) 1·0-2·0 mm wide; stamens (5-) 6 (-7), 2·5-3·5 mm long; style solitary 1·0-1·5 mm long. Fruit ovoid, densely spreading pilose with (6-) 20-40 slender, equal, glabrous spines (0·5-) 1·0-2·0 mm long.

Distribution: Eastern New South Wales, S.W. Victoria and Tasmania.

Specimens examined:

QUEENSLAND: Hubbard 8253, Glen Innes (BRI).

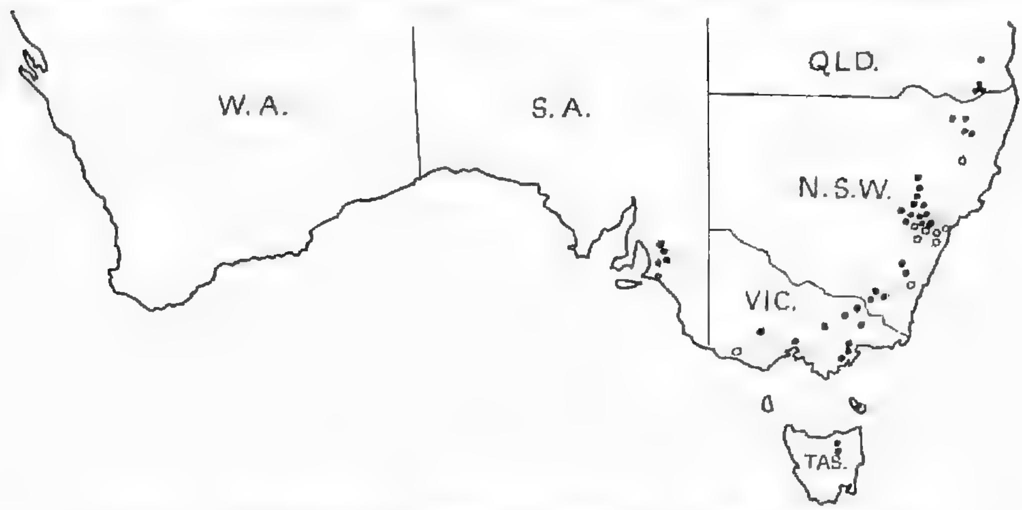
NEW SOUTH WALES: Atkinson, Blue Mountains (MEL); Cheel, Rookwood, 25.ii.1898 (NSW); Madsen, Neville, Nov. 1950 (NSW); McKee 11687, Black Mountain A.C.T. (BRI, NSW); FvM., Parramatta (MEL); Perrott, Armidale, 1871 (MEL); Wools, Parramatta (MEL).

VICTORIA: Hannaford, Warrnambool (NSW).

TASMANIA: Rodway, Bellerive, Oct. 1898 (NSW).

1B. var. **tenuispica** (Bitter) Orchard, comb. nov.

Basionym: *A. ovina* subsp. *monachena* var. *tenuispica* Bitter, Bibl. Bot. 74 (1911) 71. [Typus: "New South Wales: Jenolan Caves near Sydney leg. Blakely." Holotypus FI! isotypus NSW (95906) ("Jenolan Caves 10/1899 W. F. Blakely")!]



Map 1. Distribution of *A. agnipila* var. *agnipila* o and var. *aequispina* •.

Plant (15-) 30-50 (-66) cm tall, leaves (3·5-) 8-15 (-20) cm long, stipules triangular to linear, rarely slightly bifid at tip, 1·0-3·0 (-7·0) mm long and 1·0-1·5 mm wide, sparsely appressed pilose adaxially, moderately appressed pilose abaxially. Leaflets (11-) 17-23 (-27) per leaf with (9-) 12-15 (-17) serrations, $\frac{1}{2}$-$\frac{2}{3}$ ($\frac{3}{4}$) of the lamina width, (3·5-) 6-9 (-12) mm long and (7-) 10-15 (-19) mm wide. Spike elongate, interrupted, unbranched. Sepals 5, sparsely pilose, 1·0-2·0 mm long and (0·5-) 0·8-1·3 mm wide; (3-) 4-5 stamens, (1·0-) 1·5-2·0 (-3·0) mm long; styles 1 or rarely 2, 1·0-1·5 (-1·9) mm long. Fruit ovoid, densely spreading pilose, with (15-) 30-40 (-50) slender, equal, glabrous spines 1·0-2·0 (-3·0) mm long. Differs from var. *agnipila* in that the spike is never branched, in the fewer and shorter stamens and in the shorter stipules.

Distribution: S.E. Queensland, eastern New South Wales, central Victoria and the Mt. Lofty Ranges in South Australia. One collection is also known from the Stirling Range in S.W. Western Australia.

Selection of specimens examined:

SOUTH AUSTRALIA: Eichler 17081, 17094 and 17116, National Park, Belair (AD); Orchard 24, Torrens Gorge (AD); Symon., Nairne, 30.x.1953 (in part) (ADW).

QUEENSLAND: Anon., Canning Downs (MEL); Vanham, Toowoomba, 28.xi.1933 (BRI).

NEW SOUTH WALES: Blakely, Hornsby, Oct. 1914 (NSW); Eichler 18969, Happy Jacks Plain (AD); Hamilton, Penrith, 21.xii.1912 (NSW).

VICTORIA: Meebold 21531, Dandenong (NSW); Mueller, Port Philip (W); Muir 3635, Fryerstown (MEL); Muir 3696, Omeo-Corryong road (MEL).

WESTERN AUSTRALIA: Gardner, Red Gum Spring, Nov. 1935 (PERTH).

1C. var. **aequispina** Orchard, var. nov.

Valde similari var. *tenuispicae*, sed in fructu et spinis glabra praecipue differt. Foliola plus minusve pilosa supra, dense pilosa infra, stamina 3-4 (-5) et 1·5-2·0 mm longa, stipulae 2·0-3·5 mm longae.

Typus: Hj. Eichler 17826; Australia, New South Wales. Snowy Mountains. Near the Crackenback River at Thredbo Village. 25.i.1964. Holotypus: AD 96450044 !, isotypi: L ! NSW ! UC !.

Plant (15-) 20-35 (-60) cm tall, leaves (5-) 8-12 (-22) cm long, stipules linear to triangular, rarely slightly bifid at the tip, (1·0-) 2·0-3·5 (-5·0) mm long and (0·5-) 1·0-2·0 mm wide, glabrous or sparsely pilose adaxially, more densely appressed pilose abaxially. Leaflets (9-) 17-21 (-25) per leaf, ovate to oblong with (9-) 12-14 (-16) serrations $\frac{1}{2}$-$\frac{2}{3}$ of the depth of the lamina, (5-) 8-14 (-26) mm long and (3-) 6-8 (-13) mm wide. Spike elongate, interrupted, unbranched. Sepals 5, sparsely pilose, 1·0-2·0 mm long and 0·6-1·0 (-1·5) mm wide; (3-) 4-5 stamens, (1·0-) 1·5-2·0 (-3·0) mm long; styles, 1, 1·0-1·5 mm long. Fruit ovoid, glabrous with (12-) 30-40 (-55) equal, slender glabrous spines 1·0-2·0 mm long.

Distribution: Great Dividing Range from S.E. Queensland to central Victoria, the Mt. Lofty Range in South Australia, Tasmania and Flinders Island. One specimen is also known from the North Island of New Zealand, where it represents an introduction of the species from Australia.

Map 2. Distribution of *A. agnipila* var. *tenuispica* • and var. *protenta* o.

Selection of specimens examined:

SOUTH AUSTRALIA: Eichler 17075, Basket Range (AD); Orchard 22, 23, Torrens Gorge (AD); Orchard 6, Cherry Gardens (AD).

QUEENSLAND: Colonial Botanist, Stanthorpe 6.xi.1890 (BRI); White, Bunya Mts., Oct. 1919 (BRI).

NEW SOUTH WALES: Boorman, Molong, Nov. 1906 (NSW); Fieloes, Armidale, Nov. 1921 (NSW); Thomson, Happy Jacks Plain, 17.i.1957 (NSW).

VICTORIA: Muir 3078, Mt. Wellington (MEL); Muir 2973, Tali Karng (MEL); Walter, Victoria (BREM).

TASMANIA: Cleland, Launceston, Nov. 1912 (NSW); Whinray, Flinders Island, 20.ix.1966 (MEL).

NEW ZEALAND: Kirk, Te Aro (MEL).

1D. var. **protenta** Orchard, var. nov.

Valde similari var. *aequispinae*, sed in staminibus (5-) 6 (-7) et 4 mm longis, stipulis 4·0-5·0 mm longis, et spica ramosa prope basin vel cum fasciculis florum in axillas foliorum summorum praecipue differt.

Typus: I. B. Wilson 627, 1 mile N. of Wandilo R.S., 5.xi.1966. Holotypus: AD 96721088 !; isotypi: L ! MEL ! UC !.

Plant 20-40 cm tall, leaves (7-) 10-20 cm long, stipules linear or triangular, 4·0-5·0 mm long and 2·0-3·0 mm wide, glabrous adaxially, appressed pilose abaxially. Leaflets 18-23 per leaf, 10-17 mm long and 7-10 mm wide, with 10-13 serrations $\frac{1}{2}$-$\frac{2}{3}$ of the lamina width, sparsely pilose on the upper surface, moderately densely pilose on the lower surface. Spike elongate, interrupted, either branched at the base or else bearing large clusters of flowers in the axils of the upper leaves. Sepals 5, 1·5-2·0 mm long and 0·7-1·0 mm wide, sparsely pilose; stamens (5-) 6 (-7), 4 mm long; style 1, rarely 2, 0·9-1·5 mm long. Fruit ovoid, glabrous with 25-35 equal, slender glabrous spines 1·0-2·0 mm long.

Distribution: The type and the four specimens cited below are the only known occurrences of this variety.

Specimens examined:

SOUTH AUSTRALIA: Ising, 22.x.1927, Long Gully (AD).

QUEENSLAND: White 1734, Silverwood (BRI).

NEW SOUTH WALES: Garden, 10 miles N. of Oberon, 10.xi.1922 (NSW).

VICTORIA: Willis, Wulgulmerang, 2.xii.1962 (MEL).

2. **Acaena echinata** Nees in Lehm., Pl. Preiss. 1 (1844) 95.

[Typus: "In rupestribus umbrosis ad latus orientale montis Brown (York) d. 4 Sept., 1839 Herb. Preiss No. 2395." Holotypus: non vidi, isotypus in MEL (21944)!] Hook. f., Fl. Tasm. 1 (1856) 115 pro syn. *A. ovina*; Maiden, Useful Nat. Pl. Aust. (1889) 636 pro. syn. *A. ovina*; Bailey, Qld. Fl. 2 (1900) 529 pro syn. *A. ovina*; Bitter, Bibl. Bot. 74 (1911) 66; Eichler, Suppl. Fl. S. Aust. (1965) 169; *A. ovina* auct. non A. Cunn. in Field, Geog. Mem. of N.S. Wales (1825) 358; F.v.M., Key Syst. Vict. Pl. 2 (1885) 21, 1 (1888) 228 p.p.; Moore, Handbk. Flora N.S. Wales (1895) 175 p.p.; Black, Fl. S. Aust. ed. 1.2 (1924) 266 p.p.; Ewart, Fl. Vict. (1930) 571 p.p.; Black Fl. S. Aust. ed. 2.2 (1948) 398 p.p.

Figures: Bitter, Bibl. Bot. 74 (1911) Figs 1 and 11 (sub nom. *A. ovina* subsp. *maxima*); Black, Fl. S. Aust. ed. 1.2 (1924) Fig. 129 D-H, ed. 2.2 (1948) Fig. 556 D-H (sub nom. *A. ovina*); Blackall, W. Aust. Wildfls. 1 (1954) 182 (sub nom. *A. ovina*).

Herbaceous perennial (7-) 25-40 (-66) cm tall, stems erect or ascending, glabrous or sparsely appressed pilose. Leaves narrowly obovate to oblanceate, imparipinnate, petiolate, stipulate, (1·5-) 8-15 (-20) cm long, petiole and rachis pilose with hairs as for stems, stipules linear to triangular, (1·0-) 2·0-4·0 (-6·0) mm long and (0·5-) 1·0-3·0 mm wide, glabrous adaxially, sparsely appressed pilose or almost glabrous abaxially. Leaflets 9-15 (-21) per leaf, more or less

sessile, ovate to oblong, serrate with (6-) 8-12 (-16) serrations ½-¾ of the lamina width, (4-) 10-12 (-23) mm long and (3-) 6-10 (-13) mm wide, glabrous or very sparsely pilose on the upper surface, the hairs on the lower surface confined to the veins and/or the midrib. Sepals (4-) 5 (-6), sparsely pilose externally, 1·0-1·5 (-3·0) mm long and (0·5-) 1·0-1·5 mm wide; (2-3-) 4-5 (-8) stamens 1·0-2·0 (-5·0) mm long; 1 or rarely 2 styles 1·0-2·0 (-3·0) mm long. Fruit ovoid or with longitudinal ridges formed by concrescence of some of the spine bases, glabrous or spreading pilose, the spines unequal, barbed at the tip, glabrous or spreading pilose for ¼-¾ of their length, 3-8 longer than the others, 2·0-3·0 (-5·0) mm long, slender or with thickened conical bases; (4-6) 10-30 shorter, 0·5-2·0 mm long slender and usually glabrous.

Distribution: Eastern New South Wales, Victoria, Tasmania and the coastal regions of South Australia as far west as Streaky Bay. Several collections, including the type, are known from S.W. Western Australia, but probably represent fairly recent introductions.

Map 3. Distribution of *A. echinata* var. *echinata* o, var. *retrorsumpilosa* • and var. *tylacantha* +.

2A. var. echinata

Syn.: *A. behriana* Schldl., Linnaea 20 (1847) 660; [Typus: Behr, Sud-Australien: auf hoher gelegenem Grasland haufig im Gebiet des Gawler River, H. Behr, 1847. Holotypus: HAL! Isotypus: MEL 21939!] Hook. f. Fl. Tasm. 1 (1856) 115 pro syn. *A. ovina*; Benth., Fl. Aust. 2 (1864) 433 pro syn. *A. ovina*; Maiden, Useful Nat. Pl. Aust. (1889) 636 pro syn. *A. ovina;* Bailey, Qld. Fl. 2 (1900) 529 pro syn. *A. ovina*; Bitter, Bibl. Bot. 74 (1911) 66; Eichler, Suppl. Fl. S. Aust. (1965) 169.

A. ovina subsp. *monachena* Bitter var. *monachena*, Bibl. Bot. 74 (1911) 71. [Typus: "'Mount Koro' (: locus in tabulis geographicis neque Australiae neque Tasmaniae eruendus) herb. Vindob! (sine collectoris nomine)." Holotypus: Mount Korong, Oct. 14. W! Isotypus: Mount Korong. Oct. 14. MEL (21810)!]

A. ovina subsp. *calviscapa* Bitter, Bibl. Bot. 74 (1911) 70 p.p. [Typus: "Australia verisimiliter septentrionalis: 'Banks of the Hawkesbury at Mutallin' leg. Caley herb. Deless. Genev.! sub. nom. Ancistrum anserinifolium. herb.

Vindobl sine nom. et loco natali." Lectotypus (Orchard): Caley. Nova Hollandia. Ancistrum. W!]

Plant (7-) 25-35 (-50) cm tall, leaves (4-) 7-12 (-20) cm long, stipules triangular or linear, 1·5-2·5 (-5·0) mm long and 1·0-1·5 (-2·0) mm wide, glabrous adaxially, appressed pilose abaxially. Leaflets (9-) 13-15 (-19) per leaf with 8-13 serrations ½-¾ of the lamina width, or sometimes cut almost to the midrib, (5-) 7-10 (-15) mm long and (4-) 5-8 (-10) mm wide. Spike elongate, interrupted, unbranched. Sepals 5, almost glabrous, 1·0-1·5 (-2·5) mm long and 0·7-1·0 mm wide; (2-) 4-5 stamens, 1·0-2·0 (-3·0) mm long; style solitary 1·0-1·5 mm long. Fruit more or less angular, glabrous, spines unequal, 3-6 (-8) longer than the others, 2·0-2·5 (-4·0) mm long with more or less thickened bases, (8-) 20-30 spines shorter, usually slender, 1·0-2·0 mm long.

Distribution: S.E. New South Wales, central and eastern Victoria and South Australia from the Mt. Lofty Ranges to Streaky Bay.

Specimens examined:

South Australia: Eichler 17050, Brown Hill Creek (AD); Eichler 18758, Angaston (AD); Green 659, Clarendon (AD); Orchard 19, Chain of Ponds (AD); Richards, Lake Hamilton, Oct. 1882 (AD); Richards, Port Lincoln-Streaky Bay, 1883 (MEL); Tepper, Yorke Peninsula (MEL).

New South Wales: Rodway, Braidwood, 3.v.1925 (NSW).

Victoria: Howitt 642, Dry Gully Creek (MEL); Muir 3540, Yea district (MEL).

Western Australia: Gardner, Northam, 5.x.1942 (PERTH).

2B. var. **robusta** Orchard, var. nov.

Valde similari var. *echinatae*, sed in stipulis 3·0 mm longis, spica plerumque ramosa prope basin, staminibus (3-) 6-8, 3·5 mm longis praecipue differt.

Typus: C. R. Alcock 1666, 22.x.1967, South Australia. Southern Eyre Peninsula. Hundred of Koppio. Road between sections 65 and 215. (Hundred of Koppio is ca. 30 km. north of Port Lincoln.) Holotypus: AD 96807170!

Erect plant, 30-45 cm tall, leaves 10-17 cm long, oblanceate, stipules 3·0-6·0 mm long and 1·5 mm broad. Leaflets 13-17 per leaf, 10-12 mm long and 8-11 mm wide, more or less glabrous on the upper surface and with the hairs confined to the midrib and veins below. Spike branched at base or unbranched, but then with clusters of flowers in the axils of the upper leaves. Sepals 5, more or less glabrous, 2·0-2·5 mm long and 1·0-1·3 mm wide; (3-) 6-8 stamens, 2·5-3·5 mm long; the fruit more or less angular, glabrous, spines unequal, 4 long, 15-25 shorter. This variety differs from var. *echinata* in its longer more numerous stamens, the larger stipules and the tendence of the spike towards the branching form.

Distribution: The four specimens cited below are the only ones known of this variety.

Specimens examined:

South Australia: Alcock 1666, Hundred of Koppio (AD); Typus.

Victoria: Eckert, Wimmera, 1890 (MEL); Muir 1221, Kanya (MEL).

Western Australia: Helms, Leederville, July 1897 (PERTH).

2C. var. **subglabricalyx** (Bitter) Orchard, comb. nov.

Basionym: *Acaena ovina* subsp. *capitulata* var. *subglabricalyx* Bitter, Bibl. Bot. 74 (1911) 70. [Typus: "Plantae Mullerianae. Nov. Holland. meridional." Holotypus: W!]

Syn.: *A. ovina* subsp. *maxima* Bitter, Bibl. Bot. 74 (1911) 66 (excluding var. *retrorsumpilosa* Bitter); [Typus: none designated.]

A. ovina subsp. *capitulata* Bitter, Bibl. Bot. 74 (1911) 70 (excluding var. *subglabricalyx* Bitter). [Typus: "Australia occidentalis: Swan River, leg. Hügel nr. 132, Herb. Vindob." Holotypus: W!]

A. ovina subsp. *calviscapa* Bitter, Bibl. Bot. 74 (1911) 70 p.p. Quoad specim. Genev.!

A. pennatula Gandoger, Bull. Soc. Bot. France 59 (1912) 706. [Typus: "Australia in provincia Victoria (C. Walter)." Holotypus: LY!]

Plant (14-) 25-40 (-55) cm tall, stems sparsely appressed pilose, leaves (5-) 8-15 cm long, petiole hairs as for stems, stipules more or less triangular, (1·0-) 2·0-3·5 (-4·0) mm long and 0·5-1·5 mm wide with hairs confined to the edges. Leaflets 10-15 (-17) per leaf with (6-) 8-12 (-14) serrations ½ to ¾ of the lamina width, (6-) 8-12 (-23) mm long and (4-) 6-10 (-13) mm wide, almost or completely glabrous on the upper surface, the hairs confined to the veins on the lower surface. Spike unbranched; sepals (4-) 5, 1·5-2·0 mm long and (0·5-) 0·8-1·2 mm wide, almost glabrous; stamens 4-5, 1·0-2·0 mm long; styles solitary, rarely 2, (1·0-) 1·5-2·0 mm long. Fruit ovoid, longitudinal ridges absent, spreading pilose, the spines unequal, slender without thickened bases, 3-6 larger ones 2·0-3·0 mm long, (4-8-) 20-30 shorter ones 1·0-2·0 mm long all spreading pilose in the lower ¼-½ of their length. This variety is intermediate between *A. echinata* and *A. agnipila* in its fruit characters and possibly is the result of hybridization between them.

Distribution: S.E. New South Wales, southern Victoria and Tasmania. One specimen is also known from S.W. Western Australia.

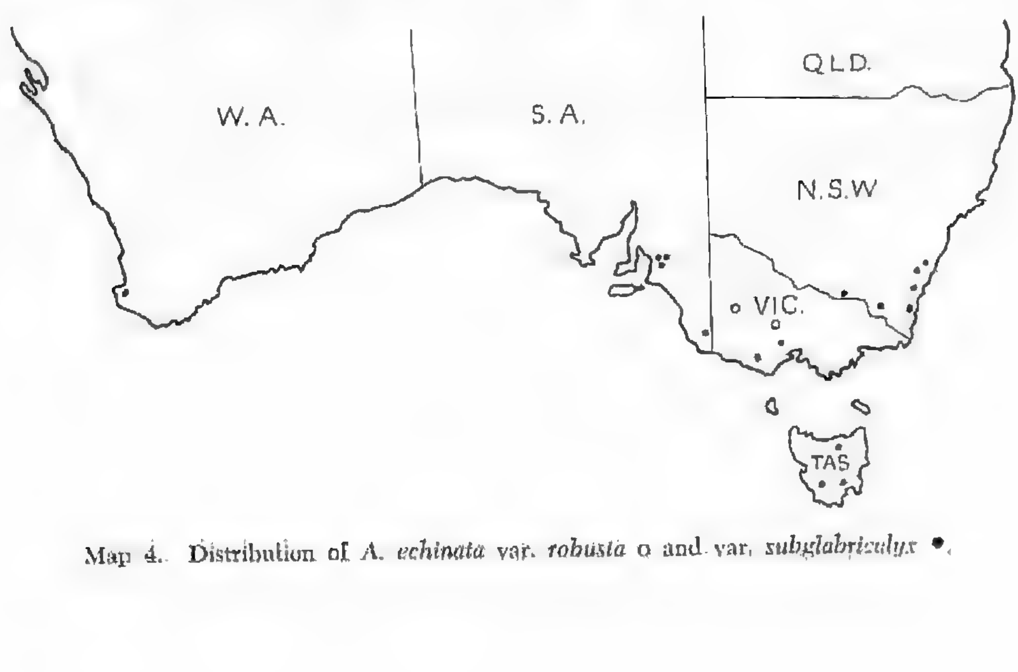
Selection of specimens examined:

New South Wales: Constable, Bungonia Caves, 23.i.1956 (NSW); Fraser, Camden, Oct. 1934 (NSW); Green, Bega, Mar. 1949 (NSW); Patterson, Albury, Oct. 1916 (NSW); Rodway, Snowball, 13.iv.1941 (NSW); Whitfeld, Kiandra, Mar. 1924 (NSW).

Victoria: Mueller, near Melbourne (W); Williamson, Hawkesdale, Nov. 1901 (NSW).

Tasmania: Bufton, Port Arthur, 1892 (MEL), Rodway, Risdon, Oct. 1898 (NSW); Rodway, River Jordan, Nov. 1898 (NSW) L.G.S. Herb. Gunn 87, Launceston (NSW).

Western Australia: Oldfield, Cape Naturaliste (MEL).



Map 4. Distribution of *A. echinata* var. *robusta* o and var. *subglabricalyx* •.

2D. var. retrorsumpilosa (Bitter) Orchard, comb. nov.

Basionym: *A. ovina* subsp. *maxima* var. *retrorsumpilosa* Bitter, Bibl. Bot 74 (1911) 69. [Typus: "Victoria: Braybrook leg. Weindorfer." Holotypus: W (6980, "Die Pflanze links")!]

Syn.: *A. ovina* subsp. *monachena* var. *laxissima* Bitter, Bibl. Bot. 74 (1911) 71. [Typus: "Queensland: Kangaroo Point. leg. Spikerman herb. Florent." Holotypus: FI!]

Plant (9-) 25-40 (-66) cm tall, stems glabrous or sparsely appressed pilose, the leaves (1·5-) 8-15 (-20) cm long, the petiole and rachis indumentum as for the stems, stipules triangular, (1·0-) 2·0-3·0 (-4·0) mm long and (0·5-) 1·0-2·0 mm wide, glabrous adaxially, sparsely appressed pilose abaxially. Leaflets 9-15 (-21) per leaf, with (7-) 10-12 (-16) serrations ½-⅗ of the lamina width, (4-) 8-12 (-20) mm long and (3-) 6-8 (-13) mm wide, glabrous or very sparsely pilose on the upper surface, the hairs on the lower surface confined to the midrib and/or veins. Spike unbranched; sepals (4-) 5, (1·0-) 1·5-2·0 mm long and (0·5-) 0·7-1·5 mm wide, more or less glabrous; (2-3-) 4-5 stamens, 1·0-2·0 (-3·0) mm long; styles solitary, rarely 2, (1·0-) 1·5-2·0 mm long. Fruit strongly longitudinally ridged, almost obpyramidal, densely spreading pilose, the spines unequal, spreading pilose in the lower ½-⅗ of their length, (3-) 6-8 (-12) longer with swollen bases forming ridges, 2·0-4·0 (-5·0) mm long, (4-6-) 20-30 shorter, often slender, 1·0-2·0 mm long.

Distribution: Mainly South Australian, confined largely to the Mt. Lofty Ranges, but also recorded for Yorke and Eyre Peninsulas. In Victoria it grades into var. *subglabricalyx*. Known also from Tasmania and S.W. Western Australia, the latter probably as a result of recent introductions.

Selection of specimens examined:

South Australia: Ising, Stirling West, 6.xi.1961 (AD); Orchard 13, Carey Gully (AD); Symon 4433, Mortlock Experimental Station (ADW); Tepper, Yorke Peninsula, 1879 (MEL).

Victoria: Croves 526, St. Albans (MEL); Morrison, Werribee, 24.ix.1892 (PERTH); Symon 1645, Horsham (ADW).

Tasmania: Rodway, Launceston, Dec. 1915 (NSW); Simson, George's Bay (BRI).

Western Australia: Cleland, Gooseberry Hill, Aug. 1908 (NSW); Oldfield, Kalgan River (MEL).

2E. var. tylacantha Orchard, var. nov.

Valde similari var. *retrorsumpilosae*, sed in habitu robustiore, spica, plerumque ramosa basin versus, stipulis (2·0-) 4·0-5·0 (-6·0) mm longis et staminibus plerumque 6 et 3·0-5·0 mm longis.

Typus: A. E. Orchard 1835, 21.xi.1968, South Australia. Mt. Lofty Ranges. Forest Range, ca. 19 km east of Adelaide. Holotypus. AD 96905096 ! isotypi: B ! K ! L ! MEL ! UC !.

Plants 25-35 (-45) cm tall, stems almost glabrous, hairs appressed. Leaves (6-) 8-14 (-20) cm long, the petiole and rachis sparsely appressed pilose, the stipules linear to triangular (2·0-) 4·0-5·0 (-6·0) mm long and 1·0-2·0 mm wide, glabrous adaxially, sparsely appressed pilose abaxially. Leaflets (11-) 13-17 (-19) per leaf with 8-12 serrations ½-⅗ of the width of the lamina, (7-) 10-15 (-18) mm long and (4-) 6-9 (-11) mm wide, glabrous or sparsely appressed pilose on the upper surface, the hairs below confined to the veins and midrib. Spike usually branched at the base, or at least with clusters of flowers in the axils of the upper leaves. Sepals (4-) 5 (-6), 2·0-3·0 mm long and 1·0-1·5 mm

wide, sparsely pilose on the outside; stamens (4-) 6, 3·0-5·0 mm long; style 1, rarely 2, 1·5-2·0 (-3·0) mm long. Fruit as for var. *retrorsumpilosa*; with 3-4 longitudinal ridges formed by concrescence of the thickened bases of 3-6 spines 2·0-3·0 mm long, with (6-) 10-20 (-30) shorter spines 0·5-2·0 mm long between the larger ones.

Distribution: Confined almost entirely to the Mt. Lofty Ranges near Adelaide. One specimen is known from Eyre Peninsula, one from S.W. Victoria, and one from S.E. New South Wales.

Specimens examined:

South Australia: Alcock B95, Yallunda Flat (AD); Cruickshank, 8.x.1967, Kersbrook (AD); Eichler 17653, Hahndorf (AD); Koch 838, Mt. Lofty (NSW); Kuchel 1254, Mt. Lofty (AD); Orchard 1833, Basket Range (AD); Spooner 222, Torrens Gorge (AD); Tate, Golden Grove, Oct. 1878 (AD).

Victoria: D'Alton 17, Dimboola (NSW); Mueller, Austral. felix (HAL).

New South Wales: Greenup, 7.ii.1962, Kiandra (Soil Conservation Herb., Cooma).

3. **Acaena ovina** A. Cunningham in B. Field, Geog. Mem. of New South Wales (1825) 358. [Typus "Frequent on moist lands, Bathurst, etc." Lectotypus: That plant attached to the label "*Acaena ovina* C. Freqt. on rather moist lands. Western Country" plus the flower spike mounted on the same sheet and obviously belonging to the same specimen. (K, non vidi, see note below)]; Hook. f., Fl. Tasm. 1 (1856) 115 p.p.; Benth., Fl. Aust. 2 (1864) 433 p.p.; Buchanan, Trans. N.Z. Inst. 3 (1871) 208 p.p.; FvM., Census 1 (1882) 47 p.p., 2 (1889) 82 p.p.; FvM., Key Syst. Vict. Pl. 2 (1885) 21, 1 (1888) 228 p.p.; Maiden, Useful Nat. Pl. Aust. (1889) 636 p.p.; Woolls, Handbk. Fl. N.S.W. (1893) 175 p.p.; Bailey, Qld. Fl. 2 (1900) 529 p.p.; Rodway, Tas. Fl. (1903) 44 p.p.; Bailey, Weeds Qld. (1906) 49 p.p.; Cheeseman, Man. N.Z. Fl. ed. 1 (1906) 1073 p.p.; Bitter, Bibl. Bot. 74 (1911) 65-72 et al., p.p.; Maiden, Weeds N.S.W. 1 (1920) 22 p.p.; Black, Fl. S. Aust. ed. 1. 2 (1924) 266 p.p.; Ewart, Fl. Vict. (1930) 571 p.p.; Cockayne and Allan, Ann. Bot. 48 (1934) 24 p.p.; Black, Fl. S. Aust. ed. 2, 2 (1948) 398 p.p.; Blackall, W. Aust. Wildflowers 1 (1954) 182 p.p.; Curtis, Stud. Fl. Tas. (1956) 172 p.p.; N.S.W. Dept. Agric., Weeds (1962) 80 p.p.; Eichler, Suppl. Black's Fl. S. Aust. (1965) 169.

Herbaceous perennial (11-) 25-60 cm tall, stems erect or ascending, moderately pubescent, the hairs usually spreading, sometimes more or less appressed. Leaves (3-) 8-12 (-20) cm long, imparipinnate, the petiole indumentum as for the stems, stipules triangular, lanceolate or linear, (1·0-) 2·0-3·5 (-5·0) mm long, 0·5-1·0 (-2·0) mm wide, usually glabrous adaxially, more or less densely appressed pilose abaxially. Leaflets (11-) 17-23 (-29) per leaf, (5-) 8-12 (-22) mm long and (3-) 5-10 mm wide, with 10-14 serrations per leaflet extending $\frac{1}{2}$-$\frac{2}{3}$ of the way to the midrib. Moderately appressed pilose on the upper surface, more or less densely pilose over the entire lower surface. Sepals 4-5, lightly pilose or almost glabrous externally, 1·0-2·5 mm long, 0·6-1·5 mm wide. 3-4 (-5) stamens, 1·0-2·0 (-4·0) mm long, style 1, 1·0-1·5 mm long. Fruit ovoid, not ribbed, spines unequal, 3-6 of length 2·0-4·0 mm, 15-30 of length 0·5-2·0 mm all lacking thickened bases.

Distribution: S.E. Queensland, eastern New South Wales, S.E. Victoria (Gippsland), northern Tasmania and S.W. Western Australia. *A. ovina* s.l. has also been recorded as an introduction in New Zealand. Its exact taxonomic status has not been determined as no material was available for comparison.

The choice of a lectotype is necessary as no single collection in Kew bears a label matching the type citation. The above is chosen as the locality is close to that cited, is in Cunningham's handwriting and matches the description fairly well. The assistance of Mr. A. B. Court, who examined the type material in Kew, is gratefully acknowledged.

3A. var. **ovina**

Plant (11-) 25-60 cm tall; leaves (3-) 10-20 cm long, stipules triangular to linear, 2·0-3·5 (-5·0) mm long, 0·7-1·0 mm wide, glabrous adaxially, appressed pilose abaxially. Leaflets (11-) 17-23 per leaf, 10-22 mm long, (3-) 5-10 mm wide, with (8-) 10-14 serrations. Fruit and spines completely glabrous, spines unequal, 3-6 longer (2·0-3·0 mm), (6-) 20-30 shorter (0·5-1·5 mm).

Distribution: S.E. Queensland, eastern New South Wales and S.E. Victoria in the Gippsland area.

Specimens seen:

QUEENSLAND: F. M. Bailey. Stanthorpe, Dec. 1875 (BRI); Everist and Webb 1312, Applethorpe (BRI).

NEW SOUTH WALES: Blakely, Bowen Park, Oct. 1906 (NSW); Boorman, Tooma, Oct. 1916 (NSW); Hamilton, Mt. Victoria, Jan. 1915 (NSW); Johnson, Braidwood, 9.xii.1950 (NSW); Milne-Curran, Upper Macquarie River, Oct. 1884 (MEL); Bauerlen 164, Tingiringi Mountains (MEL).

VICTORIA: Jephcott, Hume River 1883 (MEL); Rodway 2667, between Bairnsdale and Sale (NSW).

Map 5. Distribution of *A. ovina* var. *ovina* o, var. *velutina* • and *A.* × *anserovina* +.

3B. var. **velutina** Orchard, var. nov.

Valde similari var. *ovinae*, sed in fructu dense patenti pubescenti, pilis interdum baso spinarum praecipue differt. Spinae fructus inaequales, omnino graciles, glabrae pro parte maxima.

Typus: Hj. Eichler 18973; Australia. New South Wales. Australian Alps. Kosciusko State Park. Happy Jacks Plains [north of Happy Jacks Road, west of Tolbar Road; ca. 20 km. west-south-west of Adaminaby]. In Eucalyptus forest near the hut of Parks and Gardens (Canberra). 31.i.1967. Holotypus in AD (96714081) ! isotypi in L ! NSW ! UC !.

Perennial herb (10-) 30-50 cm tall, leaves (3-) 8-12 cm long, stipules triangular to linear, (1·0-) 2·0-4·0 (-5·0) mm long, (0·5-) 1·0-1·5 (-2·0) mm wide, glabrous or sparsely appressed pilose adaxially, more densely appressed pilose abaxially. Leaflets (11-) 17-23 (-28) per leaf, sparsely appressed pilose on the upper surface, more or less densely pilose below, (5-) 8-12 (-22) mm long, (2-) 5-8 (-10) mm wide, with (7-) 10-14 (-15) serrations extending $\frac{1}{2}$-$\frac{2}{3}$ (-$\frac{4}{5}$) of the way to the midrib. Fruit ovoid, lacking longitudinal ridges, densely spreading pilose, hairs sometimes extending to the extreme base of the spines, otherwise spines glabrous, all slender, unequal, 3-6 of length 2·4-4·0 mm, 15-30 (-50) of length 0·5-2·0 mm.

Distribution: Great Dividing Range from S.E. Queensland to the Snowy Mountains-Gippsland area, and northern Tasmania in the vicinity of Launceston. One record is known from each of S.W. Western Australia and S.E. South Australia possibly introduced.

Selection of specimens examined:

South Australia: Wahl, Lake Bonney, 1892 (MEL).

Queensland: Hickey 19, Marylands (MEL); Johnson, Glen Aplin, 4.xi.1951 (NSW); Pink, Stanthorpe, 10.x.1901 (BRI).

New South Wales: Eichler 18974, Happy Jacks' Plains (AD); Johnson, Bowral, 15.xi.1949 (NSW); Johnson and Constable, Gaird's Gap, Liverpool Range, 31.x.1954 (NSW); Thom, Wagga Wagga, 1886 (MEL).

Victoria: Muir 1017, Mt. Wellington (MEL), Muir 4570, Bryces Plain (MEL); Wilson 58, Albury (MEL).

Tasmania: Anon. ex Herb. Sonder (in part) (MEL 21043); Rodway, River Jordan, Nov. 1898 (NSW); L.G.S. Herb. Cunn 87, Launceston (NSW).

Western Australia: C. Andrews XLI, Helena River (PERTH).

4. **Acaena × anserovina** Orchard, hyb. sp. nov. (*A. anserinifolia* × *A. ovina s.l.*)
Acaena ovina var. *ambigua* Kirk, Student's Flora of New Zealand (1899) 132; [Typus: "Near Wellington." n.v. prob. J. Buchanan, on Mount Victoria, Wellington, cf. Buchanan, Trans. N. Zeal. Inst. 3 (1871) 208.] Bitter, Bibl. Bot. 74 (1911) 72.
Acaena sanguisorbae subsp. *oleosenitens* Bitter, Bibl. Bot. 74 (1911) 257. [Typus: none cited.] Figures: Bitter, l.c. figures 71, 72a, 72b.

Species hybrida, intermedia in characteribus pro parte maxima inter *A. anserinifoliam* et *A. ovinam* s.l. Caules ± erecti, non repentibus, folia obovata angusta ad oblanceata, imparipinnata, petiolis, stipulis; stipulae 1-3 fid. Flores in capitulo globoso similari *A. anserinifoliae* dispositi, sed floribus aliquot in caulem sub capitulum et in axillas foliorum superorum. Fructus globosus, obovoideus vel obconicus, 1·5-3·0 mm longus et 1·5-2·0 mm latus, dense patens pilosus; spinae omnes graciles, ± glabrae vel interdum pilosae prope basin, inequales, 3-6 magniores 2·0-5·0 mm longae, 10-20 parviores 0·5-2·0 mm longae. Typus: A. E. Orchard 1963, 11.ii.1969. Victoria, Grampians, Dwyer's Creek on Halls Gap-Dunkeld Road ca. 32 km north of Dunkeld. Holotypus: AD 96926074 ! isotypi: B ! L ! MEL ! UC !.

Intermediate in most characteristics between *Acaena anserinifolia* and *Acaena ovina* s.l. More upright, clump-forming plant than *A. anserinifolia*, lacking the creeping stems of this species. Stems erect, 20-40 cm tall, glabrous or extremely sparsely pilose with appressed hairs. Leaves 6-13 cm long, the petiole and rachis sparsely pilose with appressed hair, the stipules 1-3 fid, (2·0-) 3·0-6·0 mm long and 1·0-2·0 mm wide, glabrous adaxially, appressed pilose abaxially. Leaflets 11-17 per leaf more or less obovate, oblique at base, usually bright green on the upper surface, silver glaucous below, with (9-) 14-16 shallow serrations, (8-) 12-14 (-19) mm long and 5-10 mm wide. Upper

surface of leaflets glabrous, lower surface with the hairs confined to the veins or spreading to the mesophyll. Flowers mainly in a globular head similar to that of *A. anserinifolia* but with a few flowers scattered along the flowering stem below the head and in the axils of the uppermost leaves. Sepals 4-5, 1·5-2·0 mm long and 0·6-1·0 mm wide, glabrous or pilose on the outer face; stamens 2-5, cream, red or purple, 1·0-2·0 mm long. Fruit globular, obovoid or obconical, 1·5-3·0 mm long and 1·5-2·0 mm wide, densely spreading pilose; spines unequal, slender 3-6 longer ones in the upper part of the fruit 2·0-5·0 mm long and glabrous or pilose only towards their bases, 10-20 shorter, 0·5-2·0 mm long, glabrous.

This hybrid appears to be quite common wherever the *A. anserinifolia* complex contacts members of the *A. ovina* complex. The female parent in all cases examined in the field seems to be *A. anserinifolia*, owing largely to its slightly earlier flowering period and the proterogyny usual in the genus. In South Australia and Victoria the male parent, in those cases where this could be determined with any degree of certainty, seemed to be *A. echinata* var. *retrorsumpilosa*. In New South Wales, and probably in some cases, Victoria and South Australia, other members of the *A. ovina* complex must be acting as male parent, but the resulting hybrids are indistinguishable from each other and are therefore lumped under this one name. *A.* × *anserovina* can be fairly easily distinguished from *A. anserinifolia*, with which it is often found growing in close proximity, by its more erect habit, the flowers or fruits on the stem below the head, and the shorter spines.

Distribution: Probably occurs where *A. anserinifolia* and the *A. ovina* complex come in contact. Known from south-eastern New South Wales, Victoria, Tasmania and South Australia.

Specimens seen:

SOUTH AUSTRALIA: Eichler 17079, Belair (AD); Eichler 17676, Naracoorte (AD); Ising, 2.xii.1921, Mt. Lofty (AD); Ising, 14.xi.1935, Penola (AD); Jackson 335, Middle River, K.I. (AD); Orchard 32, Millbrook Reservoir (AD); Orchard 35, Belair (AD); Orchard 1829, Montacute (AD).

NEW SOUTH WALES: Galbraith, Kiandra, 29.i.1969 (AD); Rodway, Nerriga, 17.xi.1932 (NSW).

VICTORIA: Cowitt, Gippsland, 1882 (MEL); Muir 2763, Mt. Buller (MEL); Orchard 2012, Moleside Creek (AD).

TASMANIA: Story, Tasmania (MEL).

HYBRIDIZATION

The genus *Acaena*, in common with several other members of the family *Rosaceae*, is well known for hybridization at all taxonomic levels.

Bitter (1926), reported a generic hybrid between *Acaena argentea* and *Margyricarpus setosus* found by Skottsberg in three places on Mas a Tierra in the Juan Fernandez group of islands. The hybrid was a weak, inconspicuous plant to which he gave the name *Margyracaena skottsbergii*.

Within *Acaena* there are many reports of inter- and infra-specific hybrids. The first of these was by Buchanan (1871). He suspected that a form of *A. anserinifolia* in New Zealand, in which there were a few scattered fruits below the globular head was in fact a hybrid between *A. ovina* and *A. anserinifolia*. This plant was described by Kirk (1899) as *A. ovina* var. *ambigua*, and another by Bitter (1911) as *A. sanguisorbae* subsp. *oleosenitens*.

In his monograph Bitter devoted 26 pages to a discussion of hybrid *Acaenae*. Of the 16 hybrid taxa which he described, 15 involved a variety of *A. anserinifolia* as at least one of the parents. All of the hybrids were raised in cultiva-

tion in Bremen Botanic Garden, which unfortunately contained no plants of *A. ovina*. Many of Bitter's hybrids were later recorded in natural populations in New Zealand by Cockayne and Allan (1934). They listed 12 naturally-occurring hybrid *Acaenae*, including those of *A. ovina* with *A. microphylla*, *A. novae-zealandiae*, and 2 varieties of *A. anserinifolia*.

Dawson (1960) made a comprehensive study of naturally-occurring hybrids between *A. anserinifolia* and 2 varieties of *A. novae-zealandiae* near Wellington. He found that the postulated hybrids showed much more variation than the presumed parents, and that the seeds of the F_1 generation showed a decrease in fertility compared with the parents. Owing to protogyny in all three species and the earlier flowering period of *A. anserinifolia*, this species acted as male parent in most cases.

Hybridization almost certainly occurs between the different Australian forms and varieties of *A. anserinifolia* but the investigation of this is outside the scope of the present study. The long-recognized hybrid between the *A. anserinifolia* and *A. ovina* groups is here given species status for the first time. This hybrid species, *A. × anserovina*, can be easily recognized by the infructescence having several fruits on the stem below the globular head. The fruits may be more or less 4 angled as in *A. anserinifolia*, or almost globular, but the number of spines which is 4 in *A. anserinifolia* may be reduced to 2 or increased to about 6, but in any case the spines are shorter. The body of the fruit bears small spines as in *A. ovina* s.l. In the fruits of *A. anserinifolia* the outer layer of the receptacle is a loose papery pilose shell which is easily removed to show the bases of the spines appressed to the inner woody layer of the receptacle, while in *A. ovina* s.l. the inner and outer receptacle layers and the spine bases are all fused together. In *A. × anserovina* the receptacle is of the fused *A. ovina* type. In habit, the hybrid is intermediate between the parents, being neither as prostrate and creeping as *A. anserinifolia* nor forming such upright, compact clumps as the members of the *A. ovina* group. An examination of the fruits revealed that in every case the seed had aborted.

Within the *A. ovina* complex hybridization is also quite common. In fact, *A. ovina* s. str. and *A. echinata* var. *subglabricalyx* are probably hybrid in origin, resulting from recent contact between *A. echinata* and *A. agnipila*. Other varieties within these latter two species also grade into each other to some extent probably as a result of several crosses and backcrosses in wild populations. A comparison of *A. agnipila*, *A. ovina* and *A. echinata* is made in Table 1.

TABLE 1

Comparison of A. agnipila, A. ovina and A. echinata

	A. agnipila	*A. ovina*	*A. echinata*
Stem and petiole indumentum	dense and spreading	± dense and subappressed	sparse and appressed
Leaflet indumentum, upper surface	moderately densely pilose	glabrous to moderately pilose	glabrous
Leaflet indumentum, lower surface	densely and evenly pilose	densely and evenly pilose	pilose only on major veins
Leaflets per leaf	(9–) 17–23 (–27)	(11–) 17–23 (–29)	9–15 (–21)
Serrations per leaflet	(9–) 12–15 (–18)	10–14	(6–) 8–12 (–16)
Fruit shape	ovoid, not longitudinally ribbed	ovoid, not longitudinally ribbed	obpyrimidal, longitudinally ribbed (except var. subglabricalyx)
Spines	equal, all slender	unequal, all slender	unequal, larger ones swollen at base (except var. subglabricalyx)

HISTORY AND RELATIONSHIPS OF THE AUSTRALIAN SPECIES.

In a discussion of possible origins of and relationships within the Australian species of *Acaena*, the following points seem relevant:

1. The major centre of diversification of the genus is in South America (127 species; R. Good, 1933). Two species occur in South Africa, about 14 in New Zealand and 6 in Australia. About 4-6 more are scattered among various sub-Antarctic islands.

2. The Australian and New Zealand species fall into several different sections and sub-sections of the genus as sub-divided by Bitter (1911). Furthermore, all have closely allied species in South America, the affinities of the *A. ovina* group being with South America, with no close relatives in New Zealand.

3. Long distance dispersal of *Acaena* fruits in the down of young sea birds such as petrels (Carlquist, 1965), and shorter distance dispersal in the fur of animals is well documented (Summary: Ridley, 1930).

4. In Australia the different species are all confined to cool temperate regions with average annual rainfall of above about 12-15 inches.

5. Of the *Acaena ovina* complex, *Acaena echinata* is mainly confined to the Mt. Lofty Ranges in South Australia and the Grampians in Victoria, *A. agnipila* is commonest in the Great Dividing Range in New South Wales and eastern Victoria, and *A. ovina* s. str. occupies an intermediate position.

6. There is an intergradation between *A. echinata* and *A. agnipila* in some places, and the occurrence of intermediate plants suggests hybridization. Some of these intermediates can be referred to *A. ovina* s. str. and others to one or other of the other two species.

7. Hybrids occur between *A. anserinifolia* (usually the female parent) and species of the *A. ovina* complex. The male parent in the cases examined has always been *A. echinata* var. *retrorsumpilosa*, but further investigation may show *A. agnipila* also taking part.

8. Records of *Acaena* in Western Australia are widely scattered in time, location and in species and variety, suggesting recent introduction of the various taxa on several occasions.

The affinity of the Australian complex with South American species implies that it had its origin in Australia as an introduction into eastern Australia from South America. Furthermore, the obvious close relationship between the species within the complex supports the postulated introduction of a single taxon with subsequent diversification.

Present climatic preferences suggest that the parent species spread along the mountain systems until halted to the north in what is now southern Queensland by the increasingly tropical climate, and in the west by the aridity of Eyre Peninsula and the Nullarbor Plain.

Crocker and Wood (1947) suggested that the onset of the present arid conditions in South Australia occurred 5,000 to 9,000 years ago. Its efficient method of dispersal in the fur of animals ensured a fairly rapid spread of the colonizing *Acaena* species after its initial establishment. Thus the date of original introduction is probably no more than 10,000 years ago and possibly much less. Along with this expansion into new areas, the original species underwent diversification, with *A. echinata* evolving in the west and *A. agnipila* in the east. Besides diverging morphologically, the species developed a difference in ability to hybridize with *A. anserinifolia*, although retaining the ability to cross with each other.

During this period of expansion and diversification the original colonizing species seems to have disappeared. The only extant group that could possibly represent this ancestor is *A. ovina* s. str., which occupies a position intermediate in morphology and geographical distribution between *A. agnipila* and *A. echinata*. That this is the case, however, is unlikely, if one assumes that the derivative species evolved by better adaptation to their new environment. If the original species managed to successfully withstand the competition of its spreading derivatives, then one could expect that it would also have survived in its country of origin, particularly as the time involved is relatively short. *A. ovina* s. str. does not occur in South America, and the differences between it and its South American relatives are as great or greater than those between the Australian species. Furthermore, the occurrence of isolated plants of *A. ovina* s. str. wherever *A. echinata* and *A. agnipila* come together suggests that a hybrid origin for this species is more likely than its being the ancestral species.

Stock and fodder movements resulting from European settlement, combined with the creation of disturbed habitats such as roads and pastures over wide areas, and the weedy tendencies of the group, resulted in the rapid spread of *A. agnipila* and *A. echinata* and their subsequent contact. The result was the formation of large hybrid swarms, particularly in southern and central New South Wales. Some of these plants formed the basis of Allan Cunningham's description of *A. ovina*. European colonization also resulted in the transport of members of the complex to Western Australia and New Zealand at an early date, the type specimen of *A. echinata*, for example, being collected near Perth in 1839.

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INDEX TO NAMES

(Bold designates new taxa, new combinations or new names; italics indicate synonyms.)

SCORESBIA A NEW HYDROID GENUS FROM SOUTH AUSTRALIAN WATERS

BY JEANETTE E. WATSON*

Summary

A new genus and species of hydroid, *Scoresbia daidala* from South Australian (Flindersian) waters is described. Differences and affinities with related genera are discussed, and ecology noted.

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(*Communicated by S. A. Shepherd*)

[Read 11 September 1969]

SUMMARY

A new genus and species of hydroid, *Scoresbia daidala* from South Australian (Flindersian) waters is described. Differences and affinities with related genera are discussed, and ecology noted.

Family HALECIIDAE Hincks, 1868

Genus SCORESBIA n.gen.

(Generic name, derived from a personal name)

DIAGNOSIS

Hydrotheca borne singly on a pedicel arising directly from a creeping stolon; hydrotheca much the same diameter as the supporting pedicel and too small to lodge the retracted hydranth; hydrotheca impunctate. Hydranth with a single row of filiform tentacles. Nematothecae restricted to stolon. Reproductive zooid a fixed sporosac.

Type species: *Scoresbia daidala* n.sp.

GENERIC RELATIONSHIPS

The new genus *Scoresbia* differs from all other sporosac and nematothecae bearing haleciid genera in possessing a constantly simple unbranched pedicellate stem and nematothecae seated on the stolon at the base of the stem. It shows some affinities with *Phylactotheca* Stechow 1913, particularly *P. armata* Stechow 1924 in the shape of the hydrophores, lack of punctae and heavily ridged stem; with some sypecies of *Ophiodissa* Stechow 1919, in the lack of differentiation of the base of the hydrophore from the pedicel, and general size, e.g. *O. mirabilis* (Hincks 1868) and with the aberrant *O. carchesium* Fraser 1914 which has nematothecae scattered on the stolon. (The hydrophores in this species, however, are subsessile, and the gonosome is unknown.)

Blackburn 1938 united the three sporosac and nematothecae bearing haleciid genera *Ophiodes* Hincks 1866, *Diplocyathus* Allman 1888, and *Ophiodissa* Stechow 1919 in the single genus *Hydrodendron* Hincks 1874. This was followed by Millard (1957), Ralph (1958), and Rees and Thursfield (1965). Vervoort (1959), however, retained the genus *Hydrodendron* for those forms lacking nematothecae, and assigned to *Ophiodissa* those forms with protective structures surrounding the nematophores.

Blackburn considered the validity of *Phylactotheca* to be doubtful but allowed it to stand because of the campanulate shape of the hydrophore, differentiation of the hydrophore from the pedicel and lack of the marginal ring of puncta. He considered the shape and disposition of the nematothecae, used by

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Stechow as a basis for division of these genera, to be of little value. Nevertheless, the presence of nematothecae on the pedicel below the hydrophore in some parts of the colony at least, has long been accepted by authors as a diagnostic character.

Thus, *Hydrodendron*, *Ophiodissa* and *Phylactotheca* as generally understood, accommodate forms having shallow to deeply campanulate hydrophores, sometimes with a marginal ring of puncta. Nematothecae ranging from bell shaped to tubular are normally situated on the hydrothecal pedicel but may be additionally scattered on stem and stolon. Also, by definition, these genera relate only to branched forms (that is, those forms normally bearing at least two separate hydrophores on a stem) which may be either monosiphonic or fasicled (Leloup 1930, p. 6). However, in some species it is not unusual to find single hydrophores arising directly from the stolon (Millard 1958, p. 186) but these are probably young stems in the developmental stages and are always found interspersed among mature branched stems.

In summary, although the retention of the genera *Ophiodissa*, *Hydrodendron* and *Phylactotheca* clears up to some extent the nomenclatural difficulties surrounding the sporosac and nematothecae bearing haleciid genera, a review of this group is indicated. Whilst showing some affinities with these genera, *Scoresbia* bears no close relationship to any of them in characters of fundamental importance.

Scoresbia daidala n.sp.

(δαιδαλος—beautifully wrought, referring to the stolons and hydranth)

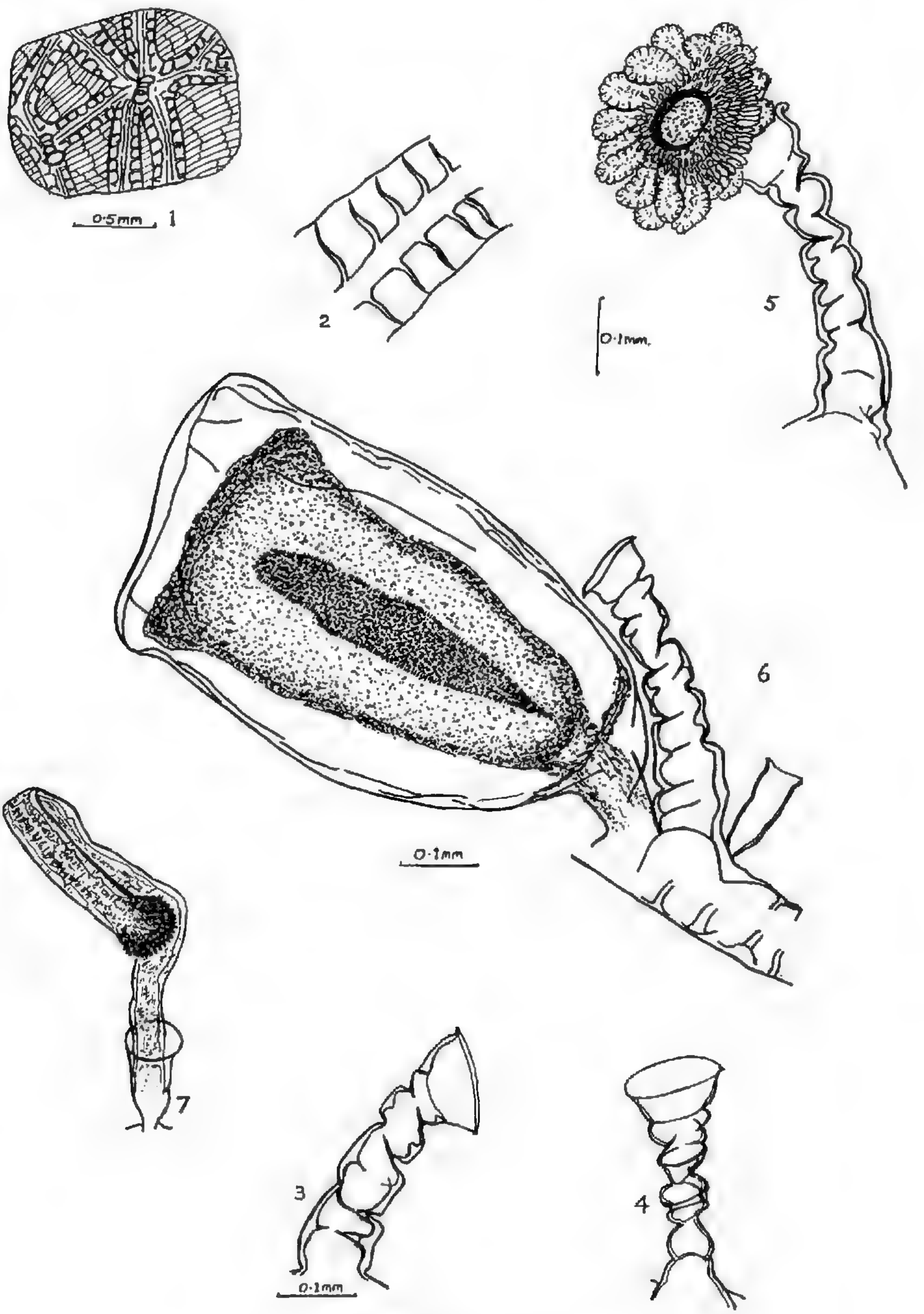
Description from the Holotype and paratypes microslides.

Hydrorhiza: a reticular network, very wide, flat and ribbon-like, strongly attached to the seaweed on which it grows (Fig. 1); divided into a central inner canal and wide outer flanges. Distinct, close, dark coloured spine-shaped markings transverse between outer and inner margins of flange (Fig. 2). Hydrorhiza widening towards base of each hydrothecal pedicel.

Stem: simple, short, erect, arising mainly at the junctions where the stolons cross; unbranched, widest at base, tapering distally, passing into hydrophore with a small constriction at narrowest part. Perisarc of stem thick, heavily ridged internally and three or four very deep oblique external constrictions dividing stem into segments, the largest at the base, becoming progressively smaller distally, the last supporting the hydrophore (Figs. 3, 4). Stem bending in a gentle curve toward distal end, bringing plane of margin of hydrophore almost perpendicular to hydrorhiza.

Hydrophore: small, bowl shaped, asymmetrical, the abcauline side usually a little longer than the adcauline side; expanding in a sinuous curve to an everted circular margin. Diaphragm present, extending across base of hydrophore in a shallow curve frequently not well seen, but position marked by a shoulder-like ledge and distinct notch in perisarc on the abcauline side and sometimes on adcauline side (Fig. 3, 5). No reduplication of margin; punctae not present; no secondary or tertiary hydrophores developed.

Fig. 1, hydrorhiza network on alga;
Fig. 2, hydrorhiza enlarged, showing markings;
Fig. 3, 4, hydrothecal pedicel; fig. 4 anterior view;
Fig. 5, extended hydranth with lenticular nematocysts;
Fig. 6, from Holotype; stem, nematotheca, and nearly mature male gonotheca, group chosen to show relative sizes, but nematotheca displaced further behind hydrothecal pedicel than usual.
Fig. 7, nematotheca and extended nematophore.



Scoresbia daidala n.sp.
Drawn from holotype and paratypes.

HYDRANTH: body thick, too large to fit retracted into hydrophore. Only slightly constricted below tentacles; tentacles stubby, 20 to 24 set in a circlet about a wide hypostome. A fringe of "lenticular nematocysts" packed about four deep surrounds hypostome at base of tentacles (Fig. 5).

NEMATOTHECAE: small, elongate urn shaped, with slightly everted margin, arising from flange of hydrorhiza usually under curve of stem directly below hydrophore, only present in younger parts of colony. Nematophore very extensile, capitate head set with nematocysts (Fig. 7).

GONOTHECA: large, obovate, smooth, somewhat flattened, tapering proximally into a short, slightly bent pedicel arising from the hydrorhiza at the base of the hydrothecal pedicel below curve of stem (Fig. 6). Width increasing to distal end; truncated by a slightly convex cap; no orifice, the contents emptied by rupture of the distal end. Male end female gonotheca same shape and size, borne on same colony.

GONOPHORES: Mature colonies bear gonangia thickly. Gonophores tend to grow in groups of the one sex, males outnumbering females in colony by at least five to one. Mature male gonophore comprises a mass of spermatogenic tissue almost filling gonotheca, supported by a blastostyle which expands in a cap across the distal end. Mature female gonophore composed of a cluster of 11 to 15 creamy coloured eggs with large yolk spots, almost filling gonotheca, surrounded by a thin blastostyle which spreads in a pinkish mass across distal end.

Mature gonophores, December to January St. Vincent Gulf (water temperature 22° C.).

Colour: perisarc pale straw colour, hydranths white.

DIMENSIONS:

(all dimensions given in mm.)

HYDRORHIZA	
maximum width	0·20-0·26
width of flange	0·05-0·09
PEDICEL OF HYDROPHORE	
length to base of hydrophore	0·24-0·37
width at junction with hydrorhiza	0·07-0·09
HYDROPHORE	
diameter at margin	0·09-0·14
diameter at diaphragm	0·07-0·08
length abcauline side (diaphragm to margin)	0·05-0·07
length adcauline side (diaphragm to margin)	0·03-0·05
NEMATOTHECA	
diameter at margin	0·05-0·06
length from base to margin	0·10-0·13
NEMATOPHORE	
maximum extended length	0·70
diameter of head	0·06-0·09
GONOTHECA	
length, excluding pedicel	0·66-0·92
greatest width	0·42-0·54
length of pedicel	0·06-0·09
HYDRANTH	
tentacle width	0·025
LENTICULAR NEMATOCYSTS	
length	0·02
width	0·005

TYPE MATERIAL AND LOCALITIES

A series of seven microslides, designated Holotype, and six paratypes, and preserved material is lodged in the National Museum of Victoria, Melbourne. One microslide, designated paratype is lodged in the South Australian Museum, Adelaide.

N.M.V. Reg. No. G1490 Holotype: 3 km. off Semaphore, St. Vincent Gulf, South Australia, on *Zonaria crenata*; depth 7 m.; coll. J.E.W.* 28/12/68.

N.M.V. Reg. Nos. G1491; G1492; G1493; G1494; S.A.M. Reg. No. H.20 paratype, from same colony as Holotype. Material fertile.

N.M.V. Reg. Nos. G1495; G1496, paratypes: West Island, Encounter Bay, South Australia: on *Zonaria crenata*: depth 25 m.; coll. J.E.W.* 29/8/68. Material infertile.

N.M.V. Reg. No. G1497: formalin preserved material, remainder of material from type locality, including fragment figured in Plate 1. Other localities: Lawrence Rocks, Portland, Victoria: on *Zonaria crenata*: coll. J.E.W.* 14/5/69. Material infertile.

REMARKS

This minute, delicate species exclusively epiphytises *Zonaria crenata*, a small brown alga ranging from central Victorian to Western Australian ocean waters, and commonly in South Australian gulf waters, in depths of 5-25 m. The association is so constant that the species of alga may be determined by the presence of the hydroid (Womersley, 1967, p. 226). Hydrophore, gonotheca, and nematotheca are very deciduous, brushing off at a touch, leaving only the stems and distinctively patterned stolons behind. Each stem curves stiffly forward at a remarkably constant angle. The asymmetrical nature of the hydranth, with foreshortening of the adcauline side further accentuates this forward bend so that the hydranth faces directly toward the growing front of the colony at the edge of the algal frond. The gonangia also share this directional growth habit; each pedicel is slightly bent, bringing the gonotheca close to the surface of the seaweed, with distal ends all pointing to the front of the colony.

The nematothecae are not often seen with the gonothecae, having dropped off the older parts of the colony, leaving no observable scars. When both are present, they are seen to be very close together, the gonothecal pedicel arising from the central canal of the hydrorhiza at the base of the stem, and the nematotheca a little to one side, on the flange of the hydrorhiza.

The thick fringe of lenticular nematocysts surrounding the hypostome has been reported previously by Ritchie (1910, p. 808) who drew attention to a "ring of very large bean shaped nematocysts 30μ long by 6μ broad surrounding the hydranth" in *Halecium simplex* Pictet, 1893, and by Huve, 1954, who reported similar large nematocysts in the intertentacular web of *Hydranthea margarica* (Hincks, 1863), *H. aloysii* (Zoja, 1893) and *Campalecium medusiferum* Torrey, 1902 (= *H. simplex*). The nematocysts of the present species fall within the size range described by these authors.

In examination of a large number of specimens I have found the hypostome to be a wide, open annulus; occasionally flatly conical. The shape observed evidently depends on the state of retraction at the time of preservation (a condition also noted by Leloup, 1939) and is therefore a character of doubtful systematic value.

The stolons can be removed with difficulty from the seaweed after treatment with hot 10% Potassium hydroxide. Viewed from the underside, the spine-shaped

(* All material collected by author, using SCUBA.)

markings are seen to be walls dividing the flanges into hollow box-like compartments. Possibly their function is to strengthen the hydrorhiza and to give added flexibility with the movements of the seaweed in the water.

ACKNOWLEDGEMENTS

I am grateful to the Director, Mr. J. McNally, and Dr. B. J. Smith of the National Museum, Melbourne, for providing facilities, and allowing me access to the hydroid collections; to Dr. H. B. S. Womersley, Botany Department, University of Adelaide, and Mr. S. A. Shepherd, who first drew my attention to this hydroid, and to the Trustees of the C.S.I.R.O. Science and Industry Endowment Fund for financial assistance in the form of a Research Grant.

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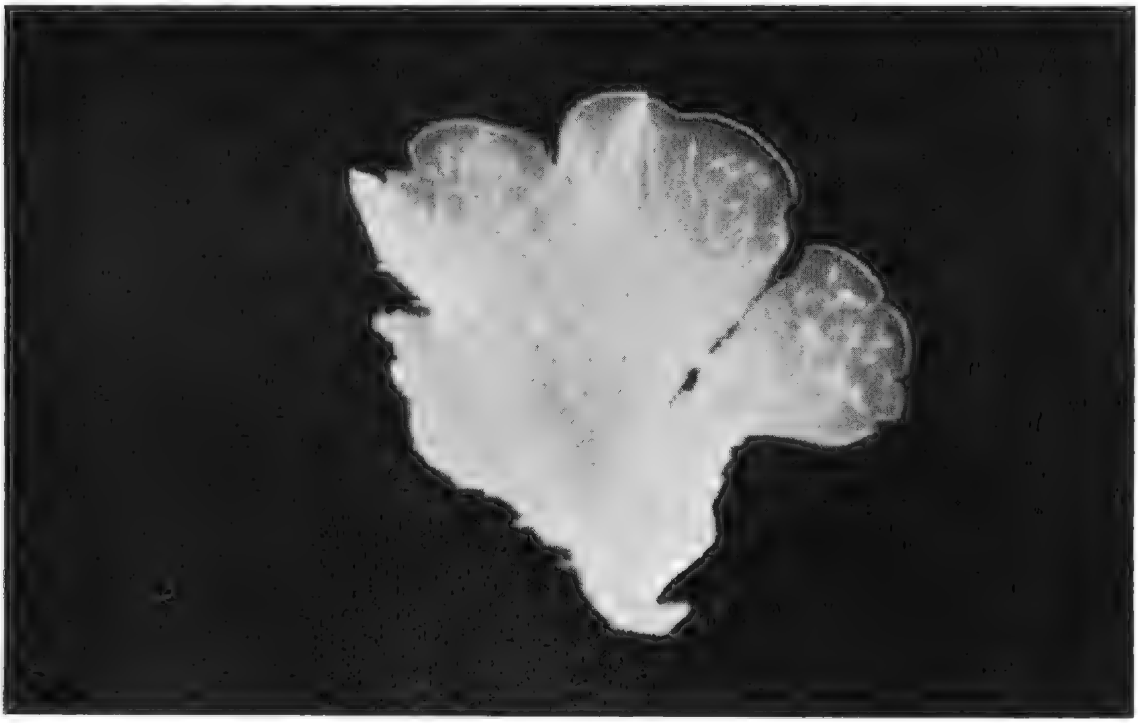

PLATE 1
Part of holotype material, on *Zonaria crenata*.

SIX NEW SPECIES OF BASSIA ALL. (CHENOPODIACEAE)

BY ERNEST H. ISING

Summary

Six new species of Bassia All. *(Chenopodiaceae)* are described, and the necessary amendments and additions to the key to the Australian species of Bassia are given [see Trans. Roy. Soc. S. Austral. 88 (1964) pp. 65-67]. Three of the species are from Western Australia, two from South Australia and one from New South Wales.

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(*Communicated by Hj. Eichler*)

[Read 11 September 1969]

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Six new species of Bassia All. (*Chenopodiaceae*) are described, and the necessary amendments and additions to the key to the Australian species of Bassia are given [see Trans. Roy. Soc. S. Austral. 88 (1964) pp. 65-67]. Three of the species are from Western Australia, two from South Australia and one from New South Wales.

1. BASSIA BEAUGLEHOLEI Ising, sp. nov. (Fig. 1 A-C)

Suffrutex; rami graciles, dense albo-tomentosi; folia anguste linearia, 10-30 mm longa, dense albo-pubescentia, obtusa, vetera saepe irregulariter flexa, juvenilia dense aureo-pubescentia; flores axillares solitarii; perianthium in fructu tomentosum, ca. 2 mm longum latumque, facies posterior brevis, concava, anterior ± convexa cum aliquot costis longitudinalibus; spinae 2, ca. 1·5 mm longae, plerumque recurvae, divergentes horizontalesve, subglabrae; tuberculum prominens, anguste oblongum, obtusum, tomentosum, secus spinam unam valde decurrens; limbus ca. 1·5 mm longus, incurvus, ciliatus, tomentosus; basis profunde cavata, grandis, ± ovata, valde obliqua, cum septis radiatis, margine lata plerumque glabra; stamina 5; stylus rectus, fere glaber; rami stigmatici 2, rubri, stylo ca. duplo longiores; semen verticale; radicula superior, longa.

Holotypus: A. C. Beauglehole 11672: Western Australia. North-West Coast Highway, ca. 45 km south-west of Tropic of Capricorn, 19.viii.1965. [AD 96929321].

Undershrub; branches slender, densely white tomentose; leaves narrow-linear, 10-30 mm long, densely white pubescent, obtuse, often irregularly bent in age, juvenile densely golden pubescent; flowers solitary in axil; fruiting perianth tomentose, about 2 mm long and wide, posterior face short, concave, anterior face ± convex with several longitudinal ribs; spines 2, about 1·5 mm long, usually recurved, divergent to horizontal, almost glabrous; tubercle prominent, narrow-oblong, obtuse, tomentose, strongly decurrent alongside one spine; limb incurved, ciliate, tomentose, about 1·5 mm long; base deeply hollowed, large, ± ovate, very oblique, radiating septa, margin broad usually glabrous; stamens 5; style straight almost glabrous, stigmatic branches 2, red, about twice as long as style; seed vertical, radicle superior, long.

Western Australia. A. C. Beauglehole 11416: AD: 40 km west of Roy Hill on Wittenoom Road, 12.viii.1965.—id. 11885: AD: 25 km north of Murchison River, ca. 340 km south of Carnarvon on the North-West Coast Highway, 22.viii.1965.

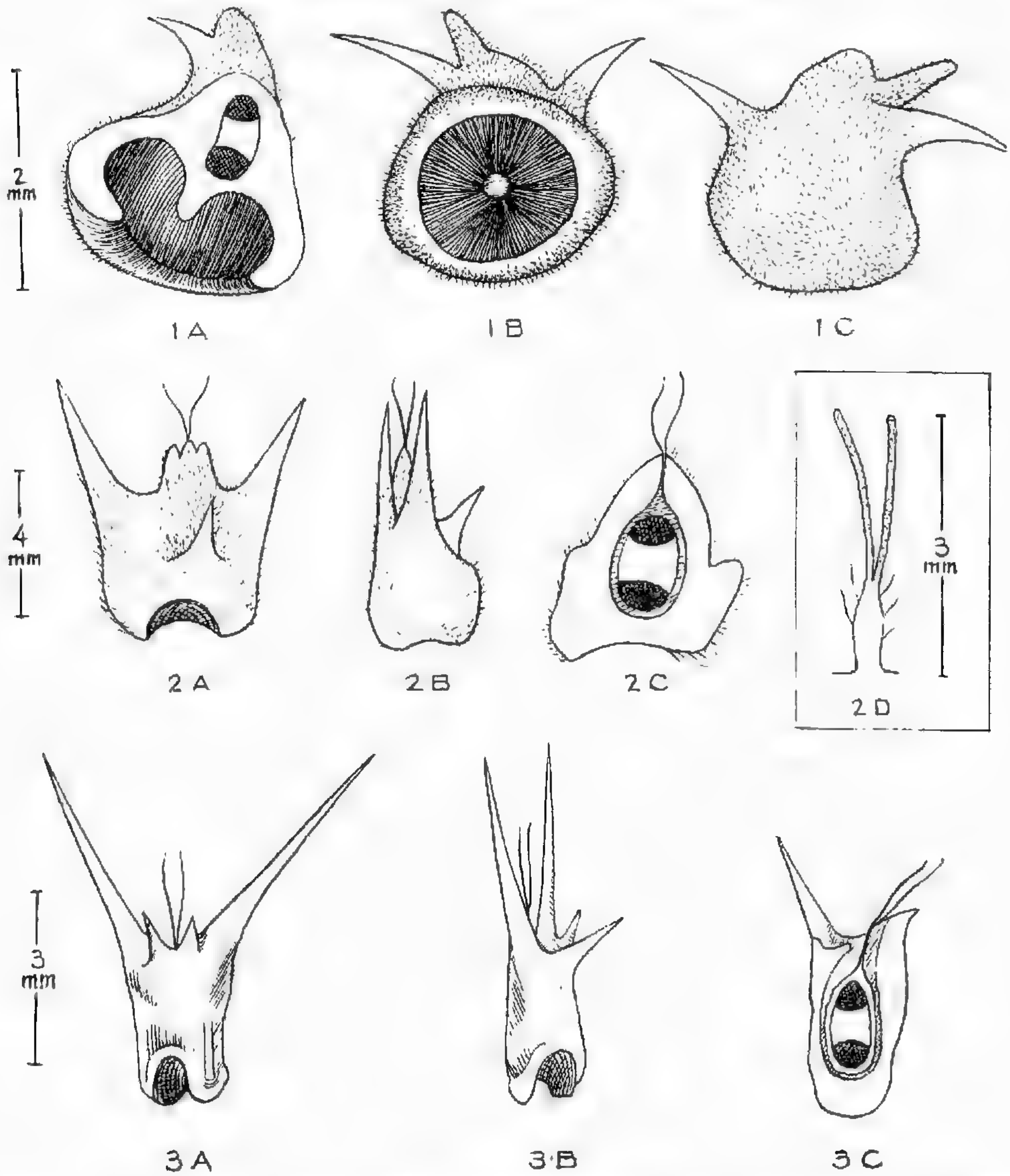
Note. This species is nearest to *B. uniflora* which has leaves ± linear clavate, 4-8 mm long, thick, perianth base smaller, spines ca. ½ mm long, straight, limb inconspicuous, style hirsute and seed horizontal to slightly oblique.

Named in honour of Mr. A. C. Beauglehole (Portland, Vic.), who has made large collections of Australian plants in recent years.

2. BASSIA COPLEYI Ising, sp. nov. (Fig. 4 A-C)

Suffrutex; rami ramulique graciles, numerosi, tomentosi, subtiliter costati; folia sessilia, conferta, linearia, 3-5 mm longa, hirsuta, acuta, incurvata; flores

E. H. Ising: Six new species of *Bassia* All. (Chenopodiaceae).



Figs. 1 to 3. Fruits of *Bassia* species (all drawings made from the holotypes).—1: *Bassia beaugleholei* Ising; 2: *Bassia stylosa* Ising; 3: *Bassia scrymgeouriae* Ising.

axillares solitarii; perianthium in fructu oblongum, cylindrico-compressum, tomentosum, 2-3 mm longum, ca. 1 mm latum, cum aliquot costis longitudinalibus, facies posterior parum concava, anterior ± convexa; spinae 2, ca. 1 mm longae, divergentes, subulatae, obtusae, plerumque tomentosae; tuberculum obtusum; limbus erectus, ciliatus, ca. 0·5 mm longus; basis oblonga, obliqua, parum cava; stylus glaber, rami stigmatici 2, rubri, ca. 1 mm longi; semen verticale; radicula superior.

Holotypus: B. Copley 1883: Australia, New South Wales. Ca. 115 km north-east of Buronga [across River Murray from Mildura]. 13.iv.1968. "A few decumbent plants to 30 cm high and 50 cm wide, grey-green." [AD 96819059].

Undershrub, branches and branchlets tomentose, finely ribbed, slender numerous. Sessile, densely placed, leaves linear, 3-5 mm long, hirsute, acute, incurved. Flowers solitary in axil. Fruiting perianth oblong, compressed-cylindrical, 2-3 mm long, ca. 1 mm wide, with several longitudinal ribs, tomentose, posterior face slightly concave, anterior face slightly convex. Spines 2, ca. 1 mm long, divergent, subulate, obtuse, usually tomentose. Tubercle obtuse, limb erect ca. 0·5 mm long, ciliate. Base oblong, oblique, slightly hollowed. Style glabrous; stigmatic branches, 2, ca. 1 mm long, red. Seed vertical; radicle superior.

Nearest to *B. caput-casuarii* Willis, which differs in the plant almost glabrous, perianth tapering to base, tubercle larger and recurved, base circular, spine 1.

Named in honour of the discoverer, Mr. Bruce Copley of Bute, South Australia, who has made extensive collections of native plants in much of Australia.

3. Bassia lanata Ising, sp. nov. (Fig. 6 A-B)

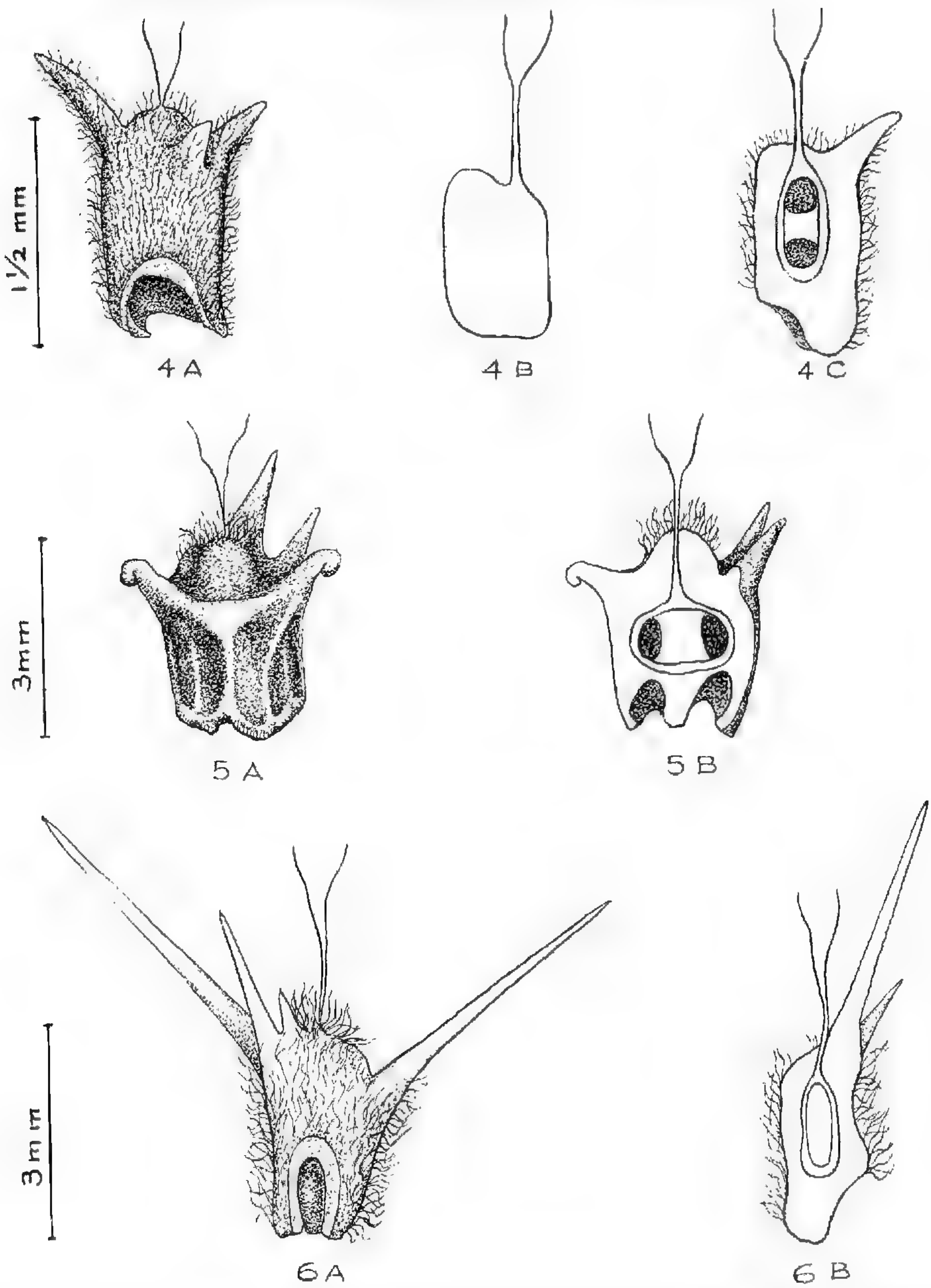
Suffrutex, pilosus, diffusus; rami teretes, ± costati, veteres fere glabri, ramuli teretes, costati, albo-lanati; folia sessilia, linearia, 5-10 mm longa, ca. 1 mm lata, pilosa (vetera fere glabra), pilis axillaribus, acuta, mucronata, plana, tenuia, rugosa, pallido-viridia, margine ad basin membranacea; flores axillares solitarii; perianthium in fructu cylindrico-compressum, ca. 3 mm longum, ca. 1 mm latum, albo-lanatum, facies anterior convexa plerumque 3 costis longitudinalibus, posterior concava, brevissima; spinae inaequales, irregulariter dispositae, plerumque 4, interdum 3, raro 2, 2 3-7 mm et ceterae 1-3 mm longae, divergentes, aciculares, graciles, glabrae (base excepto); limbus erectus, chartaceus, lanatus, ciliatus, perianthio fere longior; basis oblonga, valde obliqua, aliquantum cava, facie posteriore fere longior; stylus ca. 2 mm longus, pilosus (apice densus); rami stigmatici 2, rubri, ca. 3 mm longi; semen non visum probabiliter verticale; radicula superior.

Holotypus: T. R. N. Lothian 4944: South Australia, Lake Eyre Basin, west, Ca. 55 km south of Edwards Creek [Edwards Creek is ca. 100 km south-south-east of Oodnadatta.] "Along creek bank, rocky gibber." 31.vii.1968. [AD 96846121]

Undershrub hairy, diffuse. Branches terete, ± ribbed, white lanate. Sessile, leaves linear, 5-10 mm long, ca. 1 mm wide, pilose (nearly glabrous in age), hairs in axil, acute, mucronulate, flat, thin, rugose, pale green, base margins membranous. Flowers axillary, solitary. Fruiting perianth compressed-cylindrical, ca. 3 mm long, ca. 1 mm wide, white lanate, anterior face convex with usually 3 longitudinal ribs; posterior face concave, very short. Spines usually 4, sometimes 3, rarely 2, unequal in length and spacing, 2 longer 3-7 mm long, others 1-3 mm long, divergent, acicular, slender, glabrous except at base. Limb erect, chartaceous, lanate, ciliate, nearly as long as perianth. Base oblong, very oblique, somewhat hollowed, nearly as long as posterior face. Style pilose, densely so at summit, ca. 2 mm long. Stigmatic branches 2, red, ca. 3 mm long. Seed not seen; radicle superior.

Note. Bassia lanata is unlike any of the known species of Bassia with 4 spines and hairy perianths; the prominent features are the white lanate branchlets and perianths and the thin pale-green leaves. Many perianths were dissected but no fruits were fertile. The vertical seed cavity, which is long and narrow, suggests a vertical seed. In *B. filiformis* Ising the spines are evenly spaced and weak. *B. forrestiana* FvM. has 1 spine 20 mm long. *B. minuta* Ising has smaller, obconic

E. H. Ising: Six new species of *Bassia* All. (Chenopodiaceae).



Figs. 4 to 6. Fruits of *Bassia* species (all drawings made from the holotype).—4: *Bassia copleyi* Ising; 5: *Bassia nitida* Ising; 6: *Bassia lanata* Ising.

perianth and glabrous leaves. *B. decurrens* Black has a glabrous perianth and limb as long as perianth.

4. Bassia nitida Ising, sp. nov. (Fig. 5 A and B)

Suffrutex pilosus; rami ramulique teretes, rosei, folia anguste linearia, 7-13 mm longa, villosa, erecta, obtusa, pallido-viridia, facies abaxialis cum costa prominenti ad basim; flores axillares solitarii; perianthium in fructu cylindricum, ca. 1·5 mm longum latumque, apice concavo, glabrum, rubrum, nitidum, cum ca. 10 costis longitudinalibus prominentibus, cuius una plerumque valde decurrens; spinae ± 1 mm longae, plurumque 4, 2 rectae, ad basim junctae, 2 ± divergentes, glabrae, plerumque apicibus recurvatis; limbus erectus, ca. 0·5 mm longus, ciliatus; basis ± circularis, ca. 1 mm diametro, aliquantum cava cum 5 foveis parvis, saepe margine aliquot pili longi; stylus glaber, rami stigmatici 2, rosei, stylo ca. longiores; semen horizontale.

Holotypus: R. H. Kuchel 2684: South Australia, Northern Flinders Range, Paralana Hot Springs [ca. 115 km east-north-east of Leigh Creek]. 24.vii.1968. [AD 96839199].

Undershrub, hairy, branches and branchlets terete, pink. Leaves narrow-linear, 7-13 mm long, villous, erect, obtuse, pale green, midrib prominent at base on undersurface. Flowers axillary, solitary. Fruiting perianth cylindrical, ca. 1·5 mm long and wide, glabrous, red, shining; ribs ca. 10, longitudinal, prominent, one usually extended above summit and strongly decurrent; summit concave. Spines usually 4, ± 1 mm long, 2 straight, joined together at base, 2 usually with recurved apices ± divergent, glabrous. Limb erect, ca. 0·5 mm long, ciliate. Base ± circular, ca. 1 mm dia., somewhat hollowed with 5 small pits, margin often with a few long hairs. Style glabrous, stigmatic branches 2, ca. as long as style, pink. Seed horizontal.

Note. The unusal and remarkable features of *Bassia nitida* are the pink branches and branchlets, one rib extended higher than the summit of the perianth and strongly decurrent and two spines with recurved apices. It is nearest to *B. minuta* Ising, which has an obconic, villous perianth, all spines straight and seed vertical.

5. Bassia scrymgeouriae Ising, sp. nov. (Fig. 3 A-C)

Suffrutex ramosissimus, 8 cm altus; rami graciles, pallentes, glabri, cum costis subtilibus; folia oblanceolata, ± clavata, 4-7 mm longa, atrovirentia, rugosa, apiculata, base membranacea laevia pallidaque, cum pilis axillaribus; perianthium in fructu compresso-cylindricum, 3 mm longum, 1·5 mm latum, glabrum, brunneum dilute, vertice concavum, facies anterior vix costata longitudinaliter, posterior laevis; spinae 4, rectae, divergentes, glabrae, 2 longiores 4-9 mm, aciculares, aequales, 2 breviores 1-4 mm, plerumque subulatae, in facie posteriore apicifixae; limbus inconspicuous; erectus, ciliatus; basis ± circularis, vix cavata, obliqua; semen verticale, radicula superior, tenuis, acuta, stylo propinquo; stylus parce hirsutus, rami stigmatici 2 vel 3, rubri.

Holotypus: E. M. Scrymgeour 1472: Western Australia, 450 mile peg, North West Coastal Highway. 2.x.1966. [PERTH].

Undershrub: "dense bushlet of height 3 inches, growing in red sandy loam" [E.M.S.]; branches slender, pale, glabrous, finely ribbed; leaves oblanceolate, ± clavate, 4-7 mm long, dark green, rugose, apiculate, base membranous, smooth, pale, hairs in axil; fruiting perianth compressed cylindrical, 3 mm long, 1·5 mm wide, glabrous, pale brown, anterior face with several weak longitudinal ribs, posterior face smooth, summit concave; spines 4, straight, divergent, glabrous, 2

longer 4-9 mm, acicular, equal, 2 shorter 1-4 mm, usually subulate at summit of posterior face; limb inconspicuous, erect, ciliate; base ± circular, slightly hollowed, oblique; seed vertical, radicle superior, slender, acute, adjacent to style; style sparsely hairy, stigmatic branches 2 or 3, red.

Close to, but differs from *B. recurvicuspis* Fitzg., which has recurved shorter spines, perianth urceolate, ribs stronger.

Named in honour of the collector, Miss E. M. Scrymgeour (now Mrs. Bennett, PERTH).

6. Bassia stylosa Ising, sp. nov. (Fig. 2 A-D)

Suffrutex; rami dense-albo-hirsuti, partes juveniles aureae; linearia, folia conferta, 5-15 mm longa, ca. 1 mm lata; dense pubescentia, obtusa, apice recurva, flores axillares solitarii; perianthium in fructu ca. 1 mm longum 2 mm latum, dense pubescens, facies ± concavae cum aliquot costis longitudinalibus; spinae 3 (vel 4) divergentes, plerumque inaequales, dense pubescentes, 2 dorsales 3-7 mm longae, 1 (vel 2) in facie anteriore affixa, 1-1·5 mm longa; limbus erectus, ca. 2 mm longus, ± conicus, coriaceus, dense pubescens; basis elliptica, obliqua, vix cavata, margine villosa; stamina 5; stylus ad centrum turgidus vel deorsum dilatatus, ca. 1 mm longus, parce hirsutus, ruber vel brunneus dilute; rami stigmatici 2, ca. 2 mm longi; semen verticale, radicula superior, brevis.

Holotypus: A. C. Beauglehole 11780: Western Australia. North-West Coast Highway, ca. 170 km south-south-east of Carnarvon. 21.viii. 1965. [AD 96929337].

Undershrub; densely whitish hairy, juvenile parts golden; leaves linear, crowded; 5-15 mm long, ca. 1 mm wide, densely pubescent, obtuse, apex recurved; flowers solitary in axil; fruiting perianth ca. 1 mm long, 2 mm wide, densely pubescent, faces ± concave with several longitudinal ribs; spines 3 (or 4), 2 dorsal 3-7 mm long, 1 (or 2) on anterior face 1-1·5 mm long divergent, usually unequal, densely pubescent; limb erect, ca. 2 mm long, ± conical, coriaceous, densely pubescent; base elliptical, slightly hollowed and oblique, margin villous; stamens 5; style turgid in centre or widened downwards, ca. 1 mm long, slightly hairy, red or pale brown, stigmatic branches 2, ca. 2 mm long; seed vertical, radicle superior, short.

Differs from all other species in the swollen style, and from most others chiefly in the leaf apex recurved and juvenile parts golden.

AMENDMENT TO KEY TO AUSTRALIAN SPECIES OF *BASSIA* ALL.

In order to facilitate the determination of the new species described above the key to Australian species of *Bassia* published in Trans. Roy. Soc. S. Aust. 88:65-67(1964) is to be amended as follows:

23. Tubercle large.
    - 23b. Tubercle shorter than spines . . . . 17A. *B. beaugleholei*
    - 23b. Tubercle longer than spines.
        - 24. Perianth glabrous . . . . . 18. *B. burbidgeae*
        - 24. Perianth hairy . . . . . . 19. *B. uniflora*

23. Tubercle inconspicuous.

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39. Perianth ribbed.
    - 39a. Perianth base circular . . . . 35. *B. everistiana*
    - 39a. Perianth base oblong . . . . 35A. *B. copleyi*

39. Perianth not ribbed base ovate . . . 36. *B. patenticuspis*

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41. Perianth villous, pubescent or tomentose.
  42. Perianth villous . . . . 37. *B. lanicuspis*
  42. Perianth pubescent or tomentose.
    42a. Perianth pubescent styled turgid . . 37A. *B. stylosa*
    42a. Perianth tomentose, style linear.
      43. Spines erect or divergent, perianth swollen in lower part . . . . 38. *B. ventricosa*
      43. Spines horizontal or divergent, perianth globular . . . . 39. *B. globosa*
41. Perianth glabrous.

....

58. Perianth ca. 1½ mm long.
  58a. Perianth villous . . . . 48. *B. minuta*
  58a. Perianth glabrous . . . . . . 48A. *B. nitida*
58. Perianth ca. 3 mm long.
  59. Perianth ribbed.
    59a. Perianth glabrous . . . . . . 34. *B. decurrens*
    59a. Perianth lanata . . . . . . 34A. *B. lanata*
  59. Perianth not ribbed, sparsely tomentose . 38. *B. ventricosa*

....

65. Spines irregularly spaced, usually divergent to horizontal.
  65a. All spines divergent upwards . . . 53A. *B. scrymgeouriae*
  65a. One spine curved or erect.
    66. One spine curved horizontally, base hollowed . . . . 42. *B. andersonii*
    66. One spine erect, short, base not hollowed 40. *B. oppositicuspis*
65. Spines ± equally spaced, divergent to erect.

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I wish to thank Mr. R. D. Royce, Curator, Western Australian Herbarium, for the loan of a specimen collected by Miss E. M. Scrymgeour, and Dr. Hj. Eichler, Keeper, State Herbarium of South Australia, for facilities provided at AD to enable me to determine two Western Australian specimens collected by Mr. A. C. Beauglehole, Mr. J. Carrick for preparing Latin descriptions, and Mr. L. Dutkiewicz for preparing drawings.

INTRODUCTION TO A STUDY OF THE ECOLOGY OF THE KANGAROO ISLAND WALLABY, *PROTEMNODON EUGENII* (DESMAREST) WITHIN FLINDERS CHASE, KANGAROO ISLAND, SOUTH AUSTRALIA

BY H. G. ANDREWARTHA AND S. BARKER*

Summary

In 1919 a Fauna and Flora Reserve was established at the western end of Kangaroo Island by the South Australian Government. The area offers good opportunities for research on native mammals but it has not been used for that purpose until recently. In 1964 study on the Kangaroo Island wallaby living within the Reserve was commenced and is continuing. Despite the fact that the Kangaroo Island wallaby is a particularly fecund species and has no serious natural predators, the natural population appears to remain at a moderate density. Research into this aspect is continuing.

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In October 1919 an Act "To establish a Reserve on Kangaroo Island for the protection, preservation, and propagation of Australasian Fauna and Flora, and to provide for the control of such Reserve, and for other Purposes" became law in South Australia. This was the culmination of the efforts made by the Royal Society of South Australia, commencing in the 1890's, to have the western end of Kangaroo Island declared a Fauna and Flora Reserve. A summary of the events leading up to the passage of the Bill is given by Dixon (1920). Surprisingly, until the 1960's Flinders Chase had not been extensively used "for other purposes", namely for the scientific study of the Fauna and Flora it contained, even though for reasons to be discussed, it is an ideal locality for the study of some of the native vertebrates. A little work had been done in the 1920's however, and check-lists of the animals known to occur there had been published (Waite, 1927; Waite and Wood Jones, 1927).

The Flinders Chase Reserve

There is no recent scientific account of the physiography of Flinders Chase but a great deal of information is available in an unpublished thesis of F. H. Bauer (1960) on the regional geography of Kangaroo Island. Although the annual rainfall at the Rocky River station is 29 inches, the vegetation of the area is best described as dry sclerophyll woodland. The Rocky River station area was first included in a grazing lease in 1900. The area was taken over as an agricultural lease in 1909. In 1922 the area was reclaimed by the Crown and since then farming activities have virtually ceased. At the present time less than 100 acres remain cleared and fenced in the area surrounding the Ranger's establishment. Since the reserve was established the animals that live there have not been molested by men. Most species of animals are tame, particularly the kangaroos and the wallabies. So Flinders Chase is an ideal place for studying these animals.

Mammals

Waite and Wood Jones (1927) listed the names and status of the indigenous and introduced mammals known to occur in Flinders Chase. Both members of the

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Monotremata occur. *Tachyglossus aculeatus*, the echidna, is indigenous and abundant. The platypus, *Ornithorhynchus anatinus*, was successfully introduced into the Rocky River and is now common there and in several of the other streams. Of the three Australian superfamilies of the Marsupialia, there is no specimen record of a living Dasyurid although *Sminthopsis* sp. has been seen just outside of Flinders Chase by one of us (S.B.) and it is possible that members of both *Dasyurus* and *Antechinus* occur there. Of the Perameloidea, *Isoodon obesulus*, the short-nosed bandicoot is common. In the Phalangeroidea, both the brush-tailed possum, *Trichosurus vulpecula*, and the ring-tailed possum, *Pseudocheirus peregrinus* occur. The former is abundant and widespread. The ring-tailed possum was not recorded from the island prior to the introduction mentioned by Waite and Wood Jones (1927) so its status is uncertain. It still occurs, as a single specimen was captured, examined and released in December 1968 by one of us (S.B.). *Cercartetus nanus*, the pygmy possum occurs but because of its small size and secretive habits it is not often seen. *Cercartetus lepidus*, the Tasmanian pygmy possum, has also been collected on the Island (Aitken, 1967). *Phascolarctos cinereus*, the Koala, was introduced into Flinders Chase in 1923 and is now widespread and abundant to the point of overbrowsing and killing some of the stands of manna gum, *Eucalyptus viminalis*, its preferred food tree. The Kangaroo Island kangaroo, *Macropus fuliginosus*, is common in Flinders Chase but is now quite rare on the eastern end of the island. The Kangaroo Island wallaby, *Protemnodon eugenii*, is abundant in Flinders Chase and elsewhere on the island. No other marsupial is known to occur on the island. Of the Eutheria, very little is known of the Michrochiroptera which occur on the island. Of the Rodentia, *Rattus fuscipes greyi* occurs in varying numbers depending on the season. It is most abundant after the breeding season at the end of summer. The only other rat recorded recently is the dusky-footed swamp rat, *Rattus lutreolus*, and only isolated specimens have been captured (Horner and Taylor, 1965).

The study on the Kangaroo Island Wallaby

Because of its occurrence in great numbers the Kangaroo Island wallaby (Plate 1) presents a unique opportunity for study, as no other wallaby occurs in such numbers in South Australia. The distribution of *P. eugenii* is interesting. In historic times this wallaby occurred in large numbers on mainland South Australia (Finlayson, 1927) and it still occurs in isolated pockets on mainland Western Australia (Kelsall, 1965) although it used to be more widespread (Shortridge, 1909). Island populations still exist on East and West Wallabi Island in the Abrolhos group, Garden Island, Middle and North Twin Peaks Islands, Recherche Archipelago, all off the coast of Western Australia (Main, 1964). They were captured by Flinders in 1802 on the islands of St. Francis, St. Peter (= l'île Eugène of Peron), Thistle Island and Kangaroo Island, all of which lie off the coast of South Australia (Flinders, 1814). Flinders also captured a closely allied species on Flinders Island, South Australia and the species still occurs on the island in very small numbers. In South Australia *P. eugenii* now occurs abundantly only on Kangaroo Island. It is extinct on all of the other islands, and is likely to be extinct or occurring only in small colonies, on isolated parts of the mainland, such as those mentioned by Eyre (1847), towards the head of the Great Australian Bight. Mitchell and Behrndt (1949) recorded its introduction onto Greenly Island by fishermen. *P. eugenii* was also introduced onto Kawau Island, New Zealand, by Sir George Grey in 1870 and into the Rotorua district at an unknown date (Wodzicki and Flux, 1967). It seems possible that the animals liberated by Grey were captured on the mainland of South Australia, as at that time they were very common close to Adelaide. Wodzicki and Flux (1967) have also reported that the

Kawau animals weigh less than the Rotorua animals which are of a similar weight to the larger Kangaroo Island race. Differences between these two stocks could be determined by modern taxonomic techniques such as those reported by Martin and Hayman (1965) and Kirsch (1967). The existing colonies of *P. eugenii* present a unique opportunity for study of the evolution of macropod species.

A population study of the wallaby was commenced in Flinders Chase in November 1963. In 1961 finance was obtained to establish a field station* within Flinders Chase to be used by members of the Zoology Department. From that time periodic visits have been made to the island and as a result of these, a pool of individually marked animals has been built up.

Method of capture

On the first trip to the island it was found that individual capture of free animals with hand nets, which has been successful with the Rottnest Island quokka, *Setonix brachyurus*, could not be used because *P. eugenii* is too wary to be netted easily and can run much faster than a man pursuing it with a hand net. Accordingly a natural feature of the Rocky River station area was utilised to construct a fence-trap. The trap was built in the south-east corner of the station paddock where there is a clear demarcation between the *Acacia* scrub and a cleared grassy area. It was known that large numbers of wallabies emerge from the scrub in this area after sunset when they commence to graze. A mesh fence was built from the eastern boundary fence to the Cape de Couedic road just outside the line of *Acacia* trees. In two places swinging trap gates were fitted to the fence so that when they were set the wallabies could pass into the cleared area but couldn't pass back into the scrub. Between visits to the island the gates were left open so that the resident animals became accustomed to passing through them freely. At two corner positions on the fence short wings were built out at an oblique angle to the fence. At the end of each of these wings another wing was extended back towards the fence, and this end was made so that it could be temporarily closed off with a wire gate. At the corner point enclosed within the wings a small trap was built with an inswinging gate.

The catching procedure is to wait until at least one hour after dusk, by which time many wallabies have emerged from the scrub to feed. The operators then drive the animals slowly down the fence line and into the enclosed wing and trap area. The temporary gates are closed and the animals inside the wings and in the traps are caught with aluminium shafted hand nets, and they are then put individually into sacks. The operators who net the animals wear head torches so that both hands are free. Temporary wings, made of arc mesh, have also been used at the corners of existing fences. In one place a semi-permanent structure made from old gates is also used in a corner as a wallaby trap. At optimum times of the year, up to twenty wallabies have been captured in one night. As only smaller numbers are required, the maximum that can be caught in a single night has not been established. Up to 83 animals have been captured on a two-week trip. At the end of each trip it is noticeable that in certain areas the wallabies are much more wary than at the start of the trip and there is a fall off in nightly catching returns.

On capture each animal is marked with a monel metal ear tag (Dunnet, 1956). The animals are weighed, their foot length is measured and their teeth are

* We gratefully acknowledge the assistance of the following who voluntarily assisted in the construction of the field station. P. D. Kempster, S. R. Harris, P. C. Kempster, G. Lonzar, L. Bennett, D. Burton, Vera Burton, B. Dixon, R. Holst, C. Philpott, Dr. H. Rodda, A. Sparrow, R. Wells and A. Driver.

examined for stage of eruption. The pouch young of females are sexed and measured. In August 1966 regular sampling was commenced. Ten adult males and 30 adult females have been captured on each trip for 24-hour urine and faecal collection in metabolism cages. Blood samples have also been taken for cell counts and urea and total protein analysis. The results of this work are to be published in due course.

Behaviour

Very little is known of the social behaviour, territoriality, movements or food preferences of the wallaby. To date only one tag has been recovered outside of the study area and this came from a single female which was snared on a property about ten miles north-east of Flinders Chase less than one year after it was tagged. The wallabies which frequent the cleared area surrounding the Rocky River station commence feeding at sunset and retire into dense scrub before sunrise. They make squats in the undergrowth to sleep in, but as yet it is not known how far they move from the feeding area to a resting place, or whether they always return to the same place to sleep. Water is freely available at all times of the year from the Rocky River and from artificial watering points in the Rocky River station area. The water requirements of free living wallabies are unknown. One marked behavioural change has been noticed at different times of the year. During the early winter until green feed becomes scarce in the cleared areas, female wallabies are more abundant than males. During the summer months, males outnumber females and fewer wallabies come into the cleared areas at night. At this time of the year many animals forage under the stands of *Acacia retinodes* for seed. The numbers foraging vary according to the crop, which was heavy in 1968 and light in 1969. In the field, breeding activities are not obvious and copulation has never been observed, although males have been seen following females on several occasions in the same way as the larger male kangaroos follow the females just prior to copulation (Sharman and Pilton, 1959). The only obvious social grouping is between females and their newly emerged pouch young, which continue to follow their mothers for as long as the mothers are lactating.

There are no natural mammalian predators of wallabies on the island. Tiger cats used to occur on the island as skulls have been found in cave deposits, but they are unknown in historic times. The single instance of predation seen was the killing of a young animal that had run into a fence-trap of its own accord and was caught by a pair of wedge-tailed eagles. So far the life span is unknown. However, we have records of females that were tagged as adults in 1961 and were recaptured in the first half of 1969. These wallabies would be at least 8 years of age.

Reproduction

Some of the first observations on reproduction in this species were made by Gould (1863). His conclusions were based on data obtained by his collector, John Gilbert, from animals taken on the Abrolhos Islands in January 1843. Gould inferred that there was no regular breeding season but nevertheless gave evidence which clearly shows that there is a definite breeding season. Sharman (1955) first recorded the occurrence of delayed implantation in the Garden Island race of *P. eugenii* and this was confirmed by Sadleir and Shield (1960). In the Kangaroo Island race Berger (1966) recorded that the delayed blastocyst produced by a post partum mating in one year is held over for 11 months and is eventually born as the next season's offspring. Since the reported project commenced, measurements have been made on all pouch young examined. The birth date of each animal has been estimated from the foot and/or head measurements referred to

a standard growth curve constructed from domesticated wallabies of known birth date (C. Murphy and J. Edwards, pers. comm.). The details are presented in Figure 1. The earliest estimated birth in the field is 7th January and the latest is August 12. Most births occur from the middle of January until the middle of February. As the known gestation period is 28 days (Berger, 1966) reproductive cycles must recommence from mid-December. Field observations suggest that most females have ceased to lactate just prior to this time. However, Berger (1966) has suggested that the delay is controlled at first by lactation and later by some unknown factor.

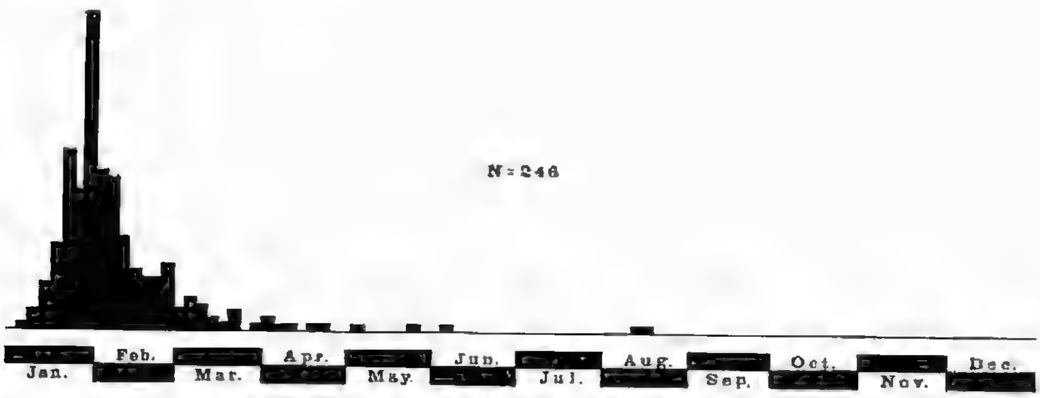

Fig. 1. Estimated birth dates of 246 pouch young Kangaroo Island wallabies measured in Flinders Chase between 1964-1969.

The Kangaroo Island wallaby is extremely fecund. The quokka, a wallaby of comparable size, breeds in its second year at the earliest, and normally does not breed until its third year. Female Kangaroo Island wallabies can produce young when less than one year of age. The youngest known animal (domesticated) was 9 months of age at her first fertile mating. Of 282 females capable of having young, which we examined in the field between 1964 and 1969 (including 1st year and aged animals) only 15 did not have young. The sex ratio of pouch young is very close to unity. Of the 246 pouch young old enough to be sexed externally, 128 were males and 118 females.

The main purpose of this investigation is to find out what controls population size. It is apparent from the length of life of some animals and from their fecundity that the potential exists for a very large population build-up. That this does not happen and in the absence of predators suggests that a high death-rate occurs at least occasionally. There is some evidence indicating that a "die-off" took place during the winter of 1968, which was wetter than average, and which followed a very dry summer. A number of dead animals were found in the study area in July 1968, an unusual occurrence as they are not usually seen. Serum protein data indicates that some infective agent may have been present in the population during 1968 (C. Murphy, pers. comm.). Work on this aspect of the problem is continuing.

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PLATE 1

Two captive male Kangaroo Island wallabies. The animal on the right is an adult male. The animal on the left is a 1½-year-old male; there is an ear-tag in the leading edge of its left ear.

DISTRIBUTION AND HABITS OF THE RABBIT BANDICOOT

*BY C. H. S. WATTS**

Summary

The known past and present distribution of the rabbit bandicoot (*Macrotis lagotis* Reid), derived from museum records and a ground survey, are plotted. Once extremely widespread, the rabbit bandicoot now occurs only in portions of the Northern Territory, central Western Australia and south-west Queensland. Possible reasons for the reduction in range are briefly discussed and a correlation between the disappearance of the bandicoot and the arrival of rabbits and foxes demonstrated.

Observations on the distribution, density and habits of the rabbit bandicoots living close to Yuendumu N.T. were made over a ten-month period.

The diet in central Australia was investigated by microscopical examination of faeces, and found to be mainly vegetable matter, most of it small seeds and underground bulbs and fungi.

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INTRODUCTION

The rabbit bandicoot (*Macrotis lagotis* Reid) was once a common and widespread animal in Australia, but is now restricted to a few areas in central Australia. Many reasons for its decline in range have been suggested but until more detailed information on the nature of the decline and the natural history of the species is forthcoming any explanation is speculative. Successful conservation of the species also depends on an understanding of the reasons behind its disappearance from many areas. In addition a more detailed overall picture of the present distribution and status of the animal is needed in order to judge, with the help of future surveys, whether or not the species is still declining in range.

This study is an attempt to bring together the existing data on the chronology of local extinction of the rabbit bandicoot and to plot its present distribution. At the same time the work on the natural history of the species begun by Smyth and Philpott (1968) has been continued.

METHODS

Information on the localities and dates of collection of the rabbit bandicoot specimens held in museums in Australia, North America and England was obtained to give a picture of the past distribution of the animal. Information on the present distribution came from the same sources, the Northern Territory Administration, and a ground survey carried out in 1968. During this survey I visited as many of the centres of habitation as possible within the area outlined by dashed lines in Fig. 2 and asked the inhabitants if they knew of any rabbit bandicoots in the vicinity. Life-sized photographs were used. If a positive report was obtained an effort was made to confirm it by visiting the locality concerned. It was assumed that only one species of rabbit bandicoot was involved, but it is possible that some of the reported sightings in south-west Queensland refer in fact to *M. minor* (Spencer) a smaller species which may still be present in the area although not collected anywhere since 1930.

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The rabbit bandicoot colonies near Yuendumu, N.T., were more closely investigated. Four visits were made to the area between February and October 1968 and an attempt made, with the assistance of the Aboriginal population, to locate all the nearby colonies. Two colonies were repeatedly visited and burrow use and distribution recorded. Unfortunately all attempts to trap the animals using a large variety of traps proved fruitless.

Fresh faecal pellets (30 or more) were collected from three areas in central Australia and their contents microscopically analysed by a method similar to that used by Watts (1968).

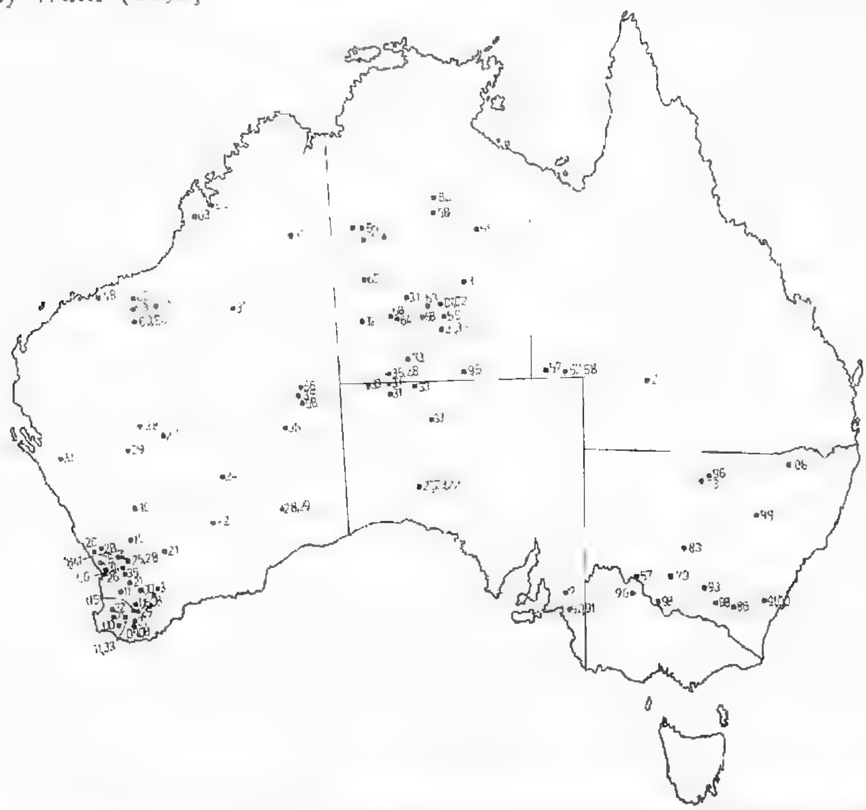

Fig. 1. Former distribution of the rabbit bandicoot based on known specimens. Numbers give collection dates.

RESULTS

Past distribution

The rabbit bandicoot was once extremely widespread, occurring over most of mainland Australia south of 18° south and west of the Great Dividing Range with the apparent exception of central Queensland and most of Victoria (Fig. 1). The species appears to have disappeared from New South Wales and southern South Australia rather suddenly around 1900 and from south-west Australia and northern South Australia in the 1930's.

This picture of sudden extermination over wide areas may to some extent represent the vagaries of collection, but seems to be marked enough to be real. An example of false record is the comparative lack of records from southern South Australia where, according to Wood-Jones (1924), the species was common around 1890.

Present distribution

At the present time the main concentration of rabbit bandicoots is in the Northern Territory to the west of the Stuart Highway, between 18° south and 24° south (Fig. 2). Outlying populations remain in south-west Queensland, the Warburton Ranges, W.A., and on the central coast of Western Australia. Whether or not the Western Australian populations are isolated from one another or from the Northern Territory population is uncertain due to the absence of recent collecting in the intervening Great Sandy Desert. The south-western Queensland population is almost certainly an isolated one.

Habitat

Rabbit bandicoots are today found over a wide range of desert and sub-desert habitats wherever the ground is soft enough to burrow in and is not subject to waterlogging. There is a tendency for burrows to be located in the more open areas and along water-courses. Illustrations of the type of habitat colonised are given by Smyth and Philpott (1968).

Food

Table I. The bulb of *Cyperus bulbosus* made up most of the diet at Papunya and was prominent in the diet at Yuendumu. In both places the animals were living close to water-courses where the plant was moderately common. On an open, wire-grass plain at Hamilton Downs, the underground fruiting bodies of the fungus *Endogone* made up much of the diet. Much of the diet at Yuendumu was composed of a small, crinkled seed not specifically identified, but resembling those of the small succulents *Calandrinia* or *Trianthema*.

Field observation at Yuendumu showed that rabbit bandicoots were eating the centres of the tap roots of *Solanum* spp. and *Boerhavia diffusa*. The unidentified fibres found in the faeces could have been from these.

Insect matter was sparse in most samples. Identifiable portions were mostly from adult Coleoptera.

Large quantities of sand occurred in all the faeces.

Social structure and habits

In the Northern Territory rabbit bandicoot colonies consist of from 7 to 28 (av. = 17, n = 6) separate burrows spread over a large and usually elongate area. Three colonies at Yuendumu covered 28, 38 and 40 acres respectively. The

TABLE I

Food types present in rabbit bandicoot faeces from three different areas of Central Australia. Figures give percentage volume

	Locality				
	Yuendumu			Hamilton Downs	Papunya
Date	2–68	4–68	7–68	7 68	4–68
Insect	2	11	6	3	2
Fungus (*Endogone*)	2	T	5	69	5
Bulb (*Cyperus*)	8	32	20	0	90
Seed (*Solanum*)	2	0	23	0	0
(? *Trianthema* or *Calandrinia*)	76	45	20	7	3
(Compositae)	0	0	0	T	0
(Other)	5	4	9	2	0
Fibre	5	8	17	20	0

T = Trace

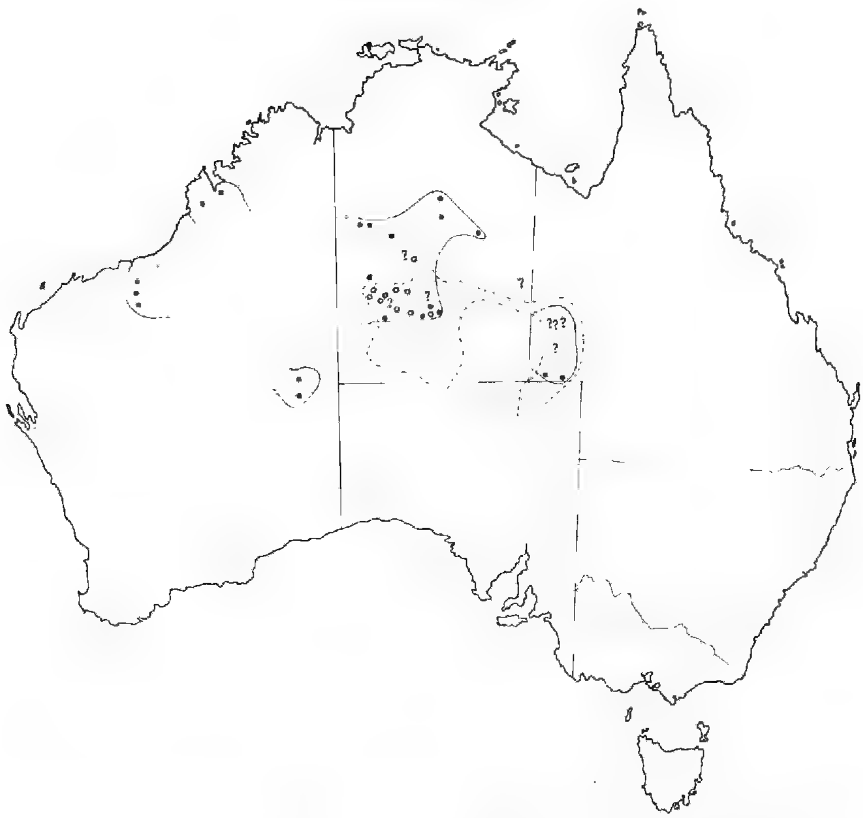

Fig. 2. Present distribution of the rabbit bandicoot. ● = locality of specimen collected in past 15 years; ○ = known locality but without specimen; ? = unsubstantiated report; - - - = area surveyed.

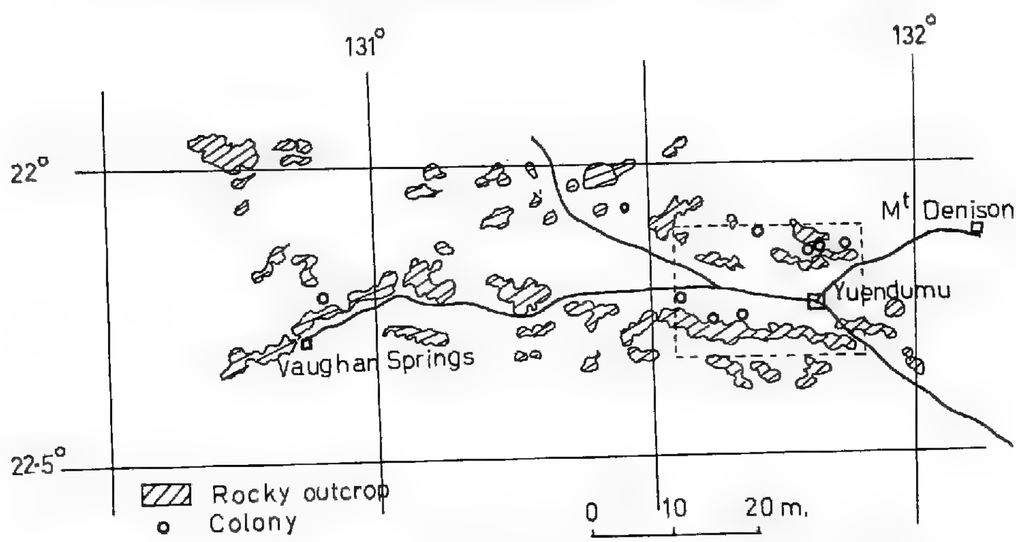

Fig. 3. Distribution of rabbit bandicoot colonies close to Yuendumu, N.T.

distribution of the burrows in a large (58 hole) colony in the Warburton Ranges has been described by Smyth and Philpott (1968) and my observations in the Northern Territory confirm their general description.

There are two basic types of burrow. The commonest is an isolated burrow about 6 in. in diameter which descends in a spiral to an average depth of 2·4 feet (1·5 to 4·0 feet, n. = 13). At Yuendumu 70% of these were under or close to a bush or fallen log. Usually there is only one complete turn and in 9 out of 13 burrows the spiral was clockwise. There is no special chamber at the end of the burrows, but the burrow usually flattens out at the end. In 2 of the 13 burrows excavated at Yuendumu a small side tunnel, most probably a bolt hole, led off the main tunnel and ended close to the surface. The second type of burrow is more complex and consists of several entrances and a series of interconnecting tunnels spread over an area of up to 100 square feet. Usually there was only one such burrow in any burrow group and it was absent from several groups. All such burrows appeared to be of long standing and probably resulted from long occupation of a favoured site. A few burrows excavated were intermediate between the two types.

From detailed observations of burrow use in one area at Yuendumu over a period of two weeks and from repeated visits to known colonies close to Yuendumu some idea of the pattern of burrow use emerged. When there is a complex burrow this is used most nights and appears to be the main sleeping quarters. The remaining burrows in the area are visited less frequently and only occasionally are used as sleeping quarters. Usually only the main burrow and one or two of the nearer single burrows are used on any one night, but on some nights, particularly rainy ones, virtually all the burrows are visited and cleaned out. When there is no large burrow in the area, a few well used burrows, often widely separated, appear to be used as sleeping quarters.

From the evidence of tracks, faeces and scratchings, rabbit bandicoots seldom move more than 100 yards from a burrow. In two instances the tracks of a large bandicoot leading away from a colony were tracked for 0·8 and 1·2 miles respectively. It is possible therefore that some inter-colony visiting takes place.

The number of individuals living in a group of burrows appears to be far fewer than first impressions would indicate. At Papunya a group of six burrows were dug up yielding one adult female. At Yuendumu a group of twelve burrows yielded an adult female and there was evidence of another individual in the vicinity, a group of twenty-eight burrows yielded an adult male, an adult female and a juvenile, and another group of burrows under detailed observation never gave evidence of being occupied by more than two individuals. Aboriginal testimony was that an adult male and female with one or occasionally two young usually occupied a group of burrows. Kreft (in Troughton, 1967) reported that in N.S.W. rabbit bandicoots lived in pairs. Thus it appears that each group of burrows is occupied by a pair and any offspring of the year.

In a three hundred square mile area close to Yuendumu I eventually located seven burrow groups (Fig. 3). Approximately a third of this area was rocky and unsuitable for bandicoots. The colony density in suitable habitat was thus roughly one per thirty square miles. Assuming an average colony size of three individuals, this works out at one rabbit bandicoot per ten square miles of suitable habitat.

DISCUSSION

The dentition of the rabbit bandicoot suggests a predominantly carnivorous diet. Field observations of fur in the stomachs of the related *M. minor* (Findlayson, 1936) and the ease with which captives dispatch mice seem to confirm this. However, Smyth and Philpott (1968) showed that in the Warburton Ranges the animal

was mainly insectivorous the bulk of the diet being termites and my observations indicate that, in Central Australia, the rabbit bandicoot is omnivorous and that at times its diet is almost totally vegetable. These results bear out Kreft's previously discredited observation that the diet in N.S.W. included bulbous roots (quoted in Troughton, 1967).

Most of the "bush tomato" (*Solanum* spp.) seeds eaten at Yuendumu were intact, suggesting that the flesh and juice of the fruit was the main attraction. About half of the seeds tentatively identified as coming from small succulents were undigested and it is possible that in this case also it was the flesh and juice of the fruit that were being sought. However, in these species the fruits are small and the least succulent part of the plant and there was no evidence of their remains in the faeces. The large quantity of these small seeds in the faeces is something of a puzzle.

Comparison of the known past and present distributions illustrates strongly the great shrinkage of range that has taken place since early settlement. Whether this shrinkage is still occurring must be left for future surveys to answer.

The reasons for the decline in range and probably also in density are difficult to identify. The decline has been from the south which implicates European man or his introductions. The fact that the animals did not disappear from New South Wales until around 1900 and were common in the settled areas close to Adelaide in the 1890's (Wood-Jones, 1924) and in the south-west until as late as 1930 suggests that European man and close settlement with the resultant alteration of habitat were not the prime causes of the rabbit bandicoot's extinction in these areas. In addition the animal has disappeared from the large reserves in north-west South Australia where there has as yet been little alteration of the habitat by man.

European man introduced the fox, rabbit and cat into Australia and all are now widespread. The cat was the earliest introduction and spread rapidly, even preceding European man into the central regions (Findlayson, 1961). Since the bandicoot and feral cat co-existed for many years the cat presumably has had little to do with the comparatively recent extermination of the bandicoot.

Rabbit bandicoots appear to have disappeared rather suddenly from New South Wales and southern South Australia around 1900, from Western Australia and northern South Australia in the 1930's, but are still present in central Australia. These dates correspond with the arrival of the fox in these areas and correlate quite well with the arrival of the rabbit which became established in southern South Australia and New South Wales around 1890 and south-west Australia and northern South Australia around 1910. Both rabbits and foxes are rare in the areas where rabbit bandicoots still exist. Thus, on this broad evidence, either or both competition for burrows by rabbits and predation by foxes could have led to the sudden demise of the rabbit bandicoot. It is probable that although the rabbit together with the cat and man's hunting, farming and ranching undoubtedly contributed greatly to the reduction in numbers and range, the coup de grace in most areas was probably delivered by the fox.

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THE VEGETATION OF PEARSON ISLANDS: A RE-EXAMINATION-FEBRUARY 1960

*BY R. L. SPECHT**

Summary

The botanical observations made on the 1960 Scientific Expedition to Pearson Islands off the west coast of Eyre Peninsula are compared with those of the 1923 Expedition. The number of angiosperm species recorded was increased by 9 to a total of 61 species; 1 fern and 7 fungal species are also recorded, and collections of marine algae were made but have not been fully determined.

A vegetation map is presented together with detailed studies on structure and composition of seven representative plant communities.

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[Read 12 June 1969]

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INTRODUCTION

In January 1923, the late Professor F. Wood Jones led a research expedition to examine the natural history of the Pearson Islands, 40 miles off the west coast of Eyre Peninsula, South Australia, in the chain of islands named the Investigator Group by Matthew Flinders in 1802. Amongst the party were T. G. B. Osborn, Professor of Botany of the University of Adelaide and Mr. T. D. Campbell. Osborn made very detailed observations on the vegetation of the Pearson Islands, and these were published in the Transactions of this Society in 1923. A short Appendix on the soils of the Islands was included by J. G. Wood.

In 1960 (Feb. 10-23), Professor T. D. Campbell led a second research expedition to the Islands. Among other natural history studies, the vegetation of these small Islands was again carefully examined and compared with the botanical collections, notes and photographs made by Osborn in 1923.

The 1960 botanical programme was as follows:—

(1) Preparation of an herbarium of all fern and angiosperm species to be found on the Islands so that changes in species composition, if any, could be compared with the collection made by Osborn in 1923.

(2) Collection of fungal, moss, lichen, and marine algal species, details of which were not included in Osborn's paper. The algal collection, made largely along the rocky shorelines, was supplemented by material dredged from around the Islands.

(3) Preparation of a detailed vegetation map of the Islands by interpreting, by land reconnaissance, recent aerial photographs of the area.

(4) Examination of the structure of characteristic plant communities and associated soils.

(5) Observation of any vegetation changes which may be obvious when sites identical to those photographed by Osborn in 1923 were again examined.

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RESULTS

The floristics and ecological relationships of the plant communities found on Pearson Islands have been adequately described by Osborn (1923). This paper aims at supplementing Osborn's paper with minimum repetition.

The major plant communities of the Islands together with notes on their habitat are summarised in Table 1. A vegetation map of the Islands (Fig. 1) derived from aerial photographs and land reconnaissance, outlines the distribution of these plant communities. Detailed notes on the structure, floristics and habitat of seven representative plant communities are given in Tables 2-8.

TABLE 1

Major plant communities recorded on Pearson Islands

Formation	Association	Habitat	Detailed records (Tables 2-8)
Low open-forest / Low woodland	*Casuarina stricta*	Granitic hills of North Island A few trees on South Island	Site 1
Closed-scrub	*Melaleuca halmaturorum*	Brackish watercourse on North Island	—
Open-scrub	*Melaleuca lanceolata*	Lower granitic hill slopes on North Island	Site 2
Open-heath (=shrub community)	(1) *Olearia ramulosa—Leucopogon parviflorus* (2) *Nitraria schoberi*	(1) Exposed granitic slopes and crevices on all Islands (2) Edge of travertine plateau on South and Middle Island	— —
Low open-scrub (=mat plant community)	(1) *Atriplex cinerea* (dwarf) (2) *Disphyma australe—Enchylaena tomentosa* (3) *Arthrocnemum halocnemoides*	(1), (2) Travertine plateau of South Island (flattened by seals) (3) A few small areas on Middle and North Islands	(1) Site 5 (2) Site 6 (3) Site 7
Low shrubland (dense phase)	(1) *Melaleuca lanceolata* (prostrate)—*Atriplex paludosa* (2) *Atriplex paludosa—Rhagodia crassifolia* (a) *Atriplex paludosa* (b) *Rhagodia crassifolia—Zygophyllum* (3) *Atriplex cinerea*	(1) On travertine on windswept south-east side of North Island (2) Lower granitic slopes, often bordering travertine of North Island and to lesser extent South Island (3) Travertine plateau of Middle Island	(1) Site 3 (2) — Site 4 (3) —

Lists of vascular plants (ferns and angiosperms) and fungi, collected on the Expedition are given in Appendix I and II respectively. There are small differences between the list of angiosperm species collected by Osborn in January 1923 and the collection made in February 1960.

The following species were not relocated: *Trichlochin muelleri*,* *Vulpia bromoides*, *Agropyron scabrum*, *Bulbinopsis semibarbata*, *Centrolepis murrayi*, *Chenopodium desertorum*,* *Westringia rigida*, *Nicotiana suaveolens*(?), *Cotula coronopifolia*, and *Sonchus asper*.

* Listed from Pearson Islands by Black (1943-57).

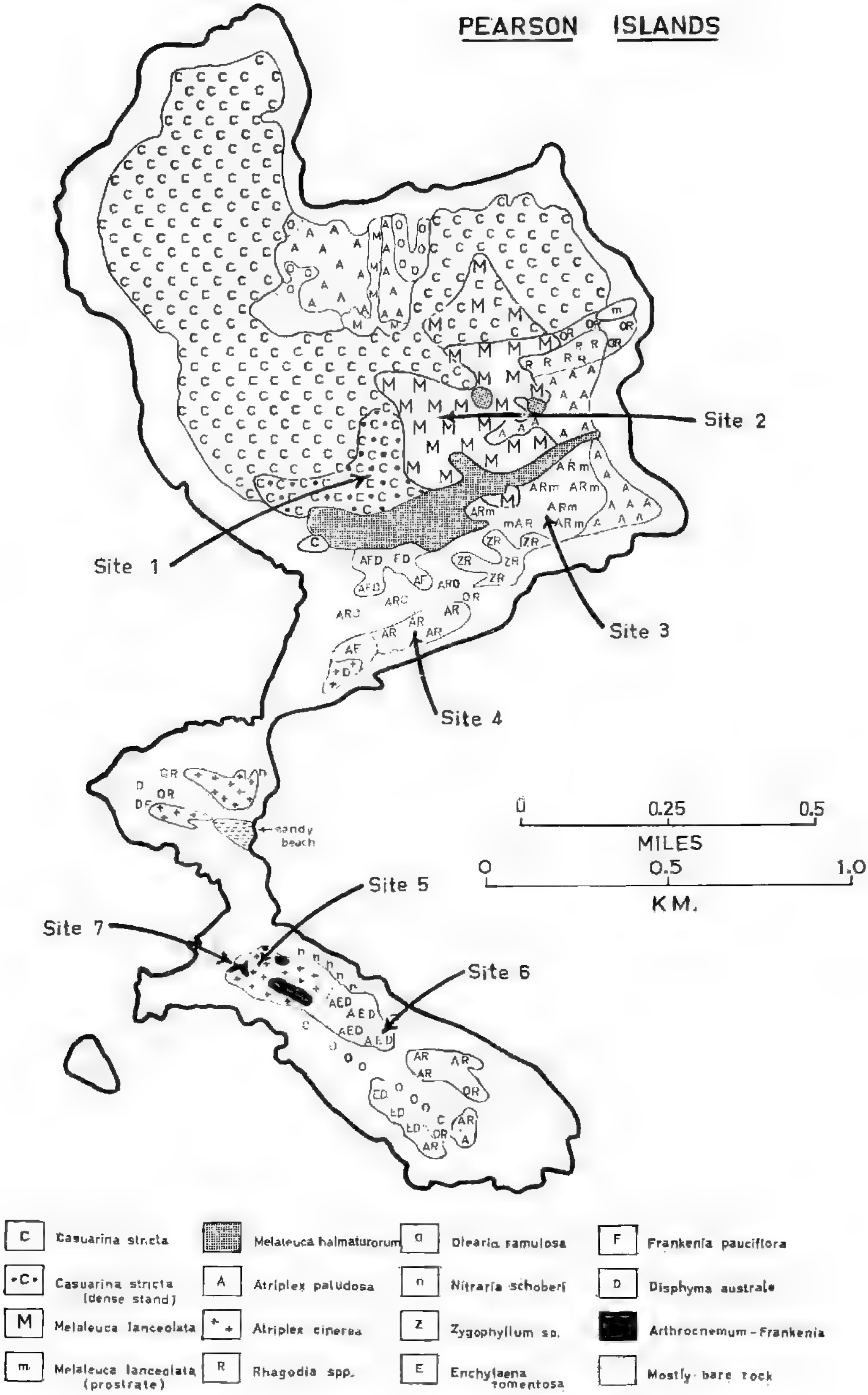

Fig. 1. Vegetation map of Pearson Islands.

TABLE 2

North Island, Site 1

Location: Edge of drainage channel on southern side of 781 Hill. (Fig. 1)
Geology: Granitic rock
Soil: 0 – 0·5 in. *Casuarina* needle litter
0·5 – 9 in. Dark grey coarse sandy loam with organic matter (pH 6·8)
9 – 12 in. Brown coarse sandy loam over decomposing granite
Animals: Wallabies common
Vegetation: (1) Formation: – Low open-forest (dense phase)
(2) Association: – *Casuarina stricta*
(3) Structure: –

Species	Height (ft.)	Canopy Projective cover %
*Casuarina stricta**	18—25	77
Correa reflexa	3—4	} 2
Rhagodia crassifolia	2	
Bare ground	—	21

*Trees per acre: 412 Trunks per tree: 1·8 (range 1-3)
Mean diam. trunk: 6·1 in. (range 2-15 in.)
Sampling technique: Eight random quadrats each 5 yards square

TABLE 3

North Island, Site 2

Location: South side of East Hill (Fig. 1)
Geology: Granitic rock
Soil: 0-0·5 in. Small amount of litter, moss and gravel
0·5-1·5 in. Dark brown sandy loam with organic matter (pH 6·4)
1·5-12 in. Brown coarse sandy loam (pH 6·6) over decomposing granite
Animals: Wallabies common
Vegetation: (1) Formation: – Open-scrub
(2) Association: – *Melaleuca lanceolata*
(3) Structure: –

Species	Height (ft.)	Canopy Projective cover %
*Melaleuca lanceolata**	8—12	46
Rhagodia crassifolia†	0·5—1·5	33
Bare ground (often exposed granite)	—	37

*Trunks per tree 3·6 (range 2-5) †Some *Rhagodia* bushes occur under *Melaleuca*
Sampling technique: Eight random line transects each 20 yards long

TABLE 4

North Island, Site 3

Location: Windswept south-east side of North Island (Fig. 1)
Geology: Travertine limestone plateau
Soil: 0-3 in. Dark brown loam with organic matter (pH 7·0)
3 in. Travertine limestone
Animals: Wallabies common
Vegetation: (1) Formation: – Low shrubland (dense phase)
(2) Association: – *Melaleuca lanceolata* – *Atriplex paludosa*
(3) Structure: –

Species	Height (inches)	Canopy† Projective cover (%)
*Melaleuca lanceolata**	10—15	33
Atriplex paludosa	12—18	42
Rhagodia crassifolia	12—18	4
Enchylaena tomentosa	12—18	2
Threlkeldia diffusa	6—9	trace
Bare ground	—	21

*Prostrate under influence of southerly winds; one specimen had a prostrate trunk 8 yards long.
†A few plants intertwine or overlap.
Sampling technique: Eight random line transects each 10 yards long.

TABLE 5

North Island, Site 4

Location: South side of North Island (Fig. 1)
Geology: Near granitic boulders close to travertine limestone plateau
Soil: Surface Small leaf litter layer
0-14 in. Brown coarse sandy loam (pH 6·8) over decomposing granite
Animals: Penguin burrows common. Wallabies common.
Vegetation: (1) Formation: - Low shrubland (dense phase)
(2) Association: *Atriplex paludosa*
(3) Structure: –

Species	Height (inches)	Canopy Projective cover (%)
Atriplex paludosa	15—24	55
Rhagodia crassifolia	6	0·5
Olearia ramulosa	12	0·5
Bare ground	—	44

Sampling technique: Eight random line transects each 10 yards long.

TABLE 6

South Island, Site 5

Location: North-east corner of travertine limestone plateau. (Fig. 1)
Geology: Travertine limestone plateau
Soil: 0-1 in. Grey brown sandy clay loam with organic matter
1-9 in. Brown sandy clay loam (pH 7·6) over travertine limestone
Animals: Seals were observed sun-baking on this area. Cape Barren geese were recorded.
Vegetation: (1) Formation: – Low open-scrub (= mat plant community)
(2) Association: – *Atriplex cinerea*
(3) Structure: –

Species	Height (inches)	Canopy Projective cover (%)
Atriplex cinerea	3—4	51
Frankenia pauciflora	3—4	1
Bare ground	—	48

Sampling technique: Eight random quadrats each 1 yard square.

TABLE 7

South Island, Site 6

Location: South-east corner of travertine limestone plateau. (Fig. 1)
Geology: Travertine limestone plateau
Soil: 0-1 in. Dark brown coarse sandy loam with organic matter (pH 8·9)
1-8 in. Brown coarse sandy loam (pH 6·9) over travertine limestone
Animals: Seals probably sun-bake on the area. Cape Barren geese were observed
Vegetation: (1) Formation: – Low open-scrub (= mat plant community)
(2) Association: – *Disphyma australe – Enchylaena tomentosa*
(3) Structure: –

Species	Height (inches)	Canopy Projective cover (%)
Disphyma australe	3—4	38
Enchylaena tomentosa	3—4	15
Threlkeldia diffusa	3—4	8
Atriplex paludosa	up to 12	2
Bare ground	–	37

Sampling technique: Eight random quadrats each 1 yard square.

TABLE 8

South Island, Site 7

Location: North-west corner of travertine limestone plateau. (Fig. 1)
Geology: Travertine limestone plateau
Soil: 0-1 in. Dark brown coarse sandy loam
1-6 in. Brown coarse sandy loam over travertine limestone
Animals: Seals probably sun-bake on this area. Cape Barren geese were observed
Vegetation: (1) Formation: – Low open-scrub (= mat plant community)
(2) Association: – *Arthrocnemum halocnemoides*
(3) Structure: –

Species	Height (inches)	Canopy Projective cover (%)
Arthrocnemum halocnemoides	2—4	50
Frankenia pauciflora	2—4	7
Bare ground	—	43

Sampling technique: Eight random quadrats each 1 yard square

The following extra species were recorded in 1960: *Scirpus congruus*(?), *Centrolepis strigosa*, *Calandrinia calyptrata*, *Stellaria media*(?), *Crassula sieberiana*, *Oxalis corniculata*, *Zygophyllum billardieri*, *Plantago varia*, and *Galium gaudichaudii*.

So far 1 species of fern, 11 species of monocotyledons and 50 species of dicotyledons have been recorded from the Islands. The supplementary list, collected February 1960, includes a number of seasonal species more of which may appear during the winter-spring seasons.

It is interesting that the tiny *Centrolepis murrayi* collected from the Islands in 1923 and recorded as a new species by Black (1923) was not relocated and yet many plants of *Centrolepis strigosa*, not collected in 1923, were found. Willis (1953) recorded both species from the Recherche Archipelago on the western side of the Great Australian Bight.

CHANGES IN THE VEGETATION

As far as possible photographs and notes made by Osborn in 1923 were matched in 1960. Within the limits of this technique, little change was obvious over much of the Islands except on the travertine plateau of the Middle Island.

Osborn recorded, both by photograph (plate IX, fig. 1) and in the text (p. 108), that an annual community of *Lepidium foliosum*, *Apium prostratum*, and *Senecio lautus* covered much of the plateau. At the junction of the travertine plateau and the talus fan derived from the granitic hill dominating Middle Island, a belt of *Atriplex cinerea*, typically a constituent of the travertine vegetation, was noted.

In 1960 *Atriplex cinerea* had extended its range to cover much of the travertine plateau (Fig. 1); no trace of the annual community could be found.

Osborn does not refer to seals on the Islands. During February, 1960, seals were common on the eastern side of Middle Island and on the north-eastern side of South Island. These heavy animals sun-baked mostly on the granitic rocks and sand near the shore line but occasionally climbed higher onto the travertine plateau. During February, 1960, they were observed sun-baking on the stunted stand (3-4 inches tall) of *Atriplex cinerea* growing on South Island (Fig. 1, Site 5). It is probable that seals may have devastated much of the *Atriplex cinerea* stand on the travertine plateau of Middle Island prior to 1923. Since that date either the seal population has fallen or the travertine plateau has become temporarily undesirable as a basking area, thus enabling *Atriplex cinerea* to recolonise the area.

Wallabies (*Petrogale pearsoni*) ranged over the whole of the North Island (presumably eating *Atriplex paludosa*), but were apparently restricted to that Island by the small strait about 100 yards wide which can be waded only at low tide.

Gillham (1960) indicated that extensive changes have occurred around penguin rookeries in Victorian sea-bird colonies. "The presence of the sea-birds leads to a broadening of the coastal belt of salt-resistant plants and elimination of the indigenous, more inland type of flora." The penguin burrows on Pearson Islands are confined to the coastal belt—in the *Atriplex paludosa—Rhagodia crassifolia*, *Atriplex cinerea*, and *Olearia ramulosa-Leucopogon parviflorus* associations of granitic slopes and detritus fans. Gillham's observations would suggest that, around penguin burrows, these communities may be gradually replaced by even more salt-resistant plants such as the "mat plant" communities—*Disphyma australe-Enchylaena tomentosa* and *Arthrocnemum halocnemoides* associations. Such a change may be slowly occurring around the small penguin rookeries on Pearson Islands but was by no means obvious.

Penguins, however, rarely burrow into the travertine plateau but prefer to nest in burrows under granitic rocks. It is thus improbable that they were the cause of the vegetation change observed on the travertine plateau of Middle Island.

ACKNOWLEDGEMENTS

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APPENDIX I

List of fern and angiosperm species collected on Pearson Islands by T. G. B. Osborn (January 1923) and R. L. Specht (February 1960). The collections have been deposited in the State Herbarium of South Australia, Botanic Gardens, Adelaide.

	Recording dates	
	Jan. 1923	Feb. 1960
Polypodiaceae		
Cheilanthes tenuifolia (Burm. f.) Swartz	*	*
Scheuchzeriaceae		
Triglochin muelleri Buch.	*	—
Gramineae		
Agrostis avenacea J. F. Gmel.	*	*
Notodanthonia racemosa (R.Br.) Zotov†	*	*
Poa poaeformis (Labill.) Druce	*	*
Vulpia bromoides (L.) S. F. Gray	*	—
Agropyron scabrum (Labill.) Beauv.	*	—
Cyperaceae		
Scirpus congruus (Nees) S. T. Blake (?)	—	*
Liliaceae		
Dianella revoluta R.Br.	*	*
Bulbinopsis semibarbata (R.Br.) Borzi	*	—
Centrolepidaceae		
Centrolepis murrayi J. M. Black	*	—
C. strigosa (R.Br.) R. & S.	—	*
Casuarinaceae		
Casuarina stricta Ait.	*	*
Chenopodiaceae		
Rhagodia baccata (Labill.) Moq.	*	*
R. crassifolia R.Br.	*	*
Chenopodium desertorum (J. M. Black) J. M. Black	*	—
Atriplex cinerea Poir.	*	*
A. paludosa R.Br.	*	*
Enchylaena tomentosa R.Br.	*	*
Threlkeldia diffusa R.Br.	*	*
Arthrocnemum halocnemoides Nees var. *pergranulatum* J. M. Black	*	*
Salicornia quinqueflora Bunge ex Ung.-Sternb.	*	*
Suaeda australis (R.Br.) Moq.	*	*
Aizoaceae		
Tetragonia amplexicoma (Miq.) Hook. f.	*	*
Carpobrotus aequilaterus (Haw.) N.E.Br.	*	*
Disphyma australe (Ait.) N.E.Br.	*	*

† Probably identified by Osborn as *Danthonia penicillata* (Labill.) F. Muell.

Portulacaceae		
Calandrinia calyptrata Hook. f.	—	•
Caryophyllaceae		
Scleranthus pungens R.Br.	•	•
Stellaria media (L.) Vill. (?)	—	•
Cruciferae		
Lepidium foliosum Desv.	•	•
Crassulaceae		
Crassula sieberiana (Schultes) Druce	—	•
Geraniaceae		
Pelargonium australe Willd.	•	•
Oxalidaceae		
Oxalis corniculata L.	—	•
Zygophyllaceae		
Nitraria schoberi L.	•	•
Zygophyllum billardieri DC. (?)	—	•
Rutaceae		
Correa reflexa (Labill.) Vent. var. *nummulariifolia* (Hook.f.) Wilson	•	•
Sapindaceae		
Dodonaea viscosa Jacq.	•	•
Rhamnaceae		
Spyridium phylicoides Reiss.	•	•
Malvaceae		
Lavatera plebeia Sims var. *tomentosa* Hook.f.	•	•
Frankeniaceae		
Frankenia pauciflora DC.	•	•
Thymelaeaceae		
Pimelea serpyllifolia R.Br.	•	•
Myrtaceae		
Melaleuca lanceolata Otto	•	•
M. halmaturorum F. Muell. ex Miq.	•	•
Calytrix tetragona Labill.	•	•
Umbelliferae		
Apium prostratum Labill. ex Vent.	•	•
Trachymene pilosa Sm.	•	•
Epacridaceae		
Leucopogon parviflorus (Andr.) Lindl.	•	•
Labiatae		
Westringia rigida R.Br. var. *dolichophylla* Ostenf.	•	—
Solanaceae		
Lycium australe F. Muell.	•	•
Nicotiana suaveolens Lehm. (?)	•	—
Myoporaceae		
Myoporum insulare R.Br.	•	•
M. deserti A. Cunn. ex Benth.	•	•
Plantaginaceae		
Plantago varia R.Br.	—	•
Rubiaceae		
Galium gaudichaudii DC.	—	•

Compositae		
Olearia ramulosa Labill.	*	*
Cotula coronopifolia L.	*	—
Ixiolaena supina F. Muell.	*	*
Cassinia spectabilis R.Br.	*	*
Calocephalus brownii F. Muell.	*	*
Senecio lautus Forst. f. ex Willd.	*	*
S. cunninghamii DC.	*	*
Sonchus asper (L.) Hill var. *littoralis* J. M. Black	*	—

APPENDIX II

List of fungal species collected on Pearson Islands by R. L. Specht (Feb. 1960) identified by Miss Judy Brown. The collection has been deposited in the mycological collection of the Waite Agricultural Research Institute.

Coriolus cinnabarinus (Jacq.) G. H. Cunn.
Corticium sp.
Fomes rimosus Berk.
Geastrum floriforme Vitt.
Hexagona decipiens Berk.
Naucoria semiorbicularis (Bull.) Fr.
Polystictus versatilis Berk.

OCCURRENCE OF POLYGONAL PATTERNED GROUND IN THE ARID ZONE OF SOUTH AUSTRALIA

BY SUSAN BARKER AND R. T. LANGE†*

Summary

A discovery of polygonal patterned ground is reported from Quondong Station in the north of the Murray Basin. The polygons are very large, possibly the largest ever described. The phenomenon is also unusual on account of the infilled trench, which soil pit sections revealed below the channels delimiting each polygon. The origin is unknown; there is a superficial resemblance to large drying cracks recorded from New Mexico.

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by SUSAN BARKER* AND R. T. LANGE†

[Read 13 November 1969]

SUMMARY

A discovery of polygonal patterned ground is reported from Quondong Station in the north of the Murray Basin. The polygons are very large, possibly the largest ever described. The phenomenon is also unusual on account of the infilled trench, which soil pit sections revealed below the channels delimiting each polygon. The origin is unknown; there is a superficial resemblance to large drying cracks recorded from New Mexico.

Patterned ground, which is a term applying to more or less symmetrical ground surface formations, is principally, but not always, found in polar, sub-polar and alpine regions. Types of this phenomenon have been described and classified by Washburn (1956). Each of the distinguishing shapes—circles, polygons, nets, steps and stripes—can be either non-sorted or sorted, the latter showing regular arrangements of stones in relation to finer material. The dimensions of the circles, nets, and polygons vary from a few centimetres to a few metres, the maximum recorded being for non-sorted polygons 25 to 30 m across in an arid temperate situation. Steps have risers 0·3 to 1·5 m and treads up to 8 m across; stripes vary in width from a few centimetres to 6 m. Numerous hypotheses regarding the origins of these forms are also discussed by Washburn; most concern the effects of freezing and thawing and have no application to the Australian arid zone, but one hypothesis concerns contraction due to drying and may be relevant.

The occurrence of different types of patterned ground or gilgai in warm temperate Australia has been described by Hallsworth (1955, 1968). This surface morphology is referred to as "small scale undulations, the alternate hummocks (puffs, mounds) and hollows (shelves, crab-holes, melon-holes) of which show some degree of regularity". Six major types of gilgai are recognised—normal, melon-hole, stony, lattice, linear or wavy and tank gilgai. Only the stony gilgai which occurs widely in the arid regions appears to be sorted. Tank gilgai records the largest dimensions, the mounds being up to 10 m across and the depressions up to 20 m long.

A remarkable new kind of patterned ground has been found in arid country in South Australia, which does not conform to any of the morphological descriptions given in the reviews cited above. The discovery was made on Quondong Station in the plains of the Murray Basin lying between the River Murray and the Olary Spur. The area is one of low rainfall (average 175 mm per annum). The country is gently undulating and geologically consists of Tertiary marine sediments covered by calcareous Pleistocene and Recent deposits. The calcareous soils are underlain by calcrete and are classified as solonized brown soils in the Handbook of Australian Soils (ed. by Stace *et al.*, 1968) and as Gc soils by the Factual Key (Northcote, 1965).

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The phenomenon was first observed during a ground survey of the vegetation of Quondong, when straight-sided channels 0·3 to 0·5 m wide by 7 to 30 cm deep and up to about 20 m long were noticed. Examination of aerial photographs revealed whole systems of these channels or gutters forming a roughly polygonal pattern (see Fig. 1). Each polygon was approximately 50 to 100 m across, dimensions which are far in excess of other patterned ground mentioned in the literature. The characteristic puff appearance of gilgai was absent, though the vertical sides of the channels gave the impression that rifting might have occurred; there was no evidence of sorting of stones from fines, even though nodular calcrete occurs a few centimetres below the ground surface. The ground in the area does not undulate but slopes gently to the S.E. where there is a small swamp about 1·25 km away.

TABLE 1

Location: Quondong Station, N.E. of South Australia. Chowilla 1 : 250,000 map (S1 54-6) grid. ref. 327291 140°17′E and 33°00′20″S.

Profile 1: Samples taken from infilled trench below gutter, Principal profile form Gc1·12.

Depth	Description	% Clay	% Total soluble salts	% Organic carbon	% $CaCO_3$
0–5 cm	Dark reddish brown, powdery sandy loam	14	·030	·59	3·1
5–13 cm	Dark reddish brown, powdery sandy loam	16	·029	·49	4·4
13–28 cm	Dark reddish brown, powdery sandy clay loam	17	·029	·44	6·4
28—48 cm	Dark reddish brown, powdery sandy clay loam	16	·029		9·1
48–69 cm	Yellowish red, powdery sandy clay loam	15	·031		11·0
69–79 cm	Yellowish red, massive hard sandy clay loam	17	·097		46·0

Profile 2: Samples taken from undisturbed soil to one side of gutter. Principal profile form Gc1·12

Depth	Description	% Clay	% Total soluble salts	% Organic carbon	% $CaCO_3$
0–5 cm	Dark reddish brown, powdery sandy loam	15	·028	·38	3·1
5–13 cm	Dark reddish brown, powdery sandy clay loam	17	·029	·35	9·0
13–28 cm	Dark reddish brown, weakly cemented massive sandy clay loam	18	·032	·24	13·0
28–43 cm	Yellowish red, hard weakly cemented massive loamy clay	20	·032		18·0
43–79 cm	Yellowish red, hard weakly cemented massive loamy clay	17	·086		43·0

A limited investigation was carried out, the results of which are outlined here. Two soil pits were dug to a depth of approximately 0·9 m across two of the channels, one a well formed channel 0·3 m deep (see Fig. 2) and one a shallow gutter 10 cm deep. Below both the channel and the gutter (see Fig. 3) was a narrow vertical trench apparently infilled with material which may be from the top of the profile. This vertical trench was remarkable for its straight sides and flat bottom.

The gutter was given further examination and samples from the centre of the gutter through the infilled section (Profile 1) and from the undisturbed section to one side (Profile 2) were subjected to chemical and physical analyses (see Table 1). Although the profiles are similar the analyses show differences that are of interest. In the infilled trench there is a higher percentage of organic carbon throughout the profile, and lower percentages of calcium carbonate and clay in the 28 to 43 cm horizon, than in the undisturbed soil. The trench also shows a marked increase in calcium carbonate from 11% to 46%, whereas the soil to the side of the trench has a more gradual increase in calcium carbonate.

These extremely large polygonal segments and the clearly defined channels cannot be very old. In places, roots of the black oak (*Casuarina cristata*) bridge the channels, which must, therefore, have developed after the roots had grown. However, the cause of the microrelief is not known. A rather similar patterned ground on a playa surface in New Mexico (Lang 1943) was attributed to drying cracks. The polygons in this case were 25 to 30 m across, and delimited by broad faint depressions about 1 m wide and 3 cm deep in the middle, which were picked out on aerial photographs by the concentration of shrubs in the grooves. The channels found at Quondong were not in a swamp or depression where water collects. The vegetation is a black oak-bluebush association with *Cassia* sp. and bullock bush. The channels have been observed in other parts of the Station where dense black oak woodland obscures the pattern from the air.

ACKNOWLEDGEMENTS

We are greatly indebted to Mr. K. H. Northcote and Mr. R. Campbell of the C.S.I.R.O. Division of Soils, Urrbrae, S.A., who examined the soils in the field, and Mr. A. R. P. Clark under whose direction the analyses were made.

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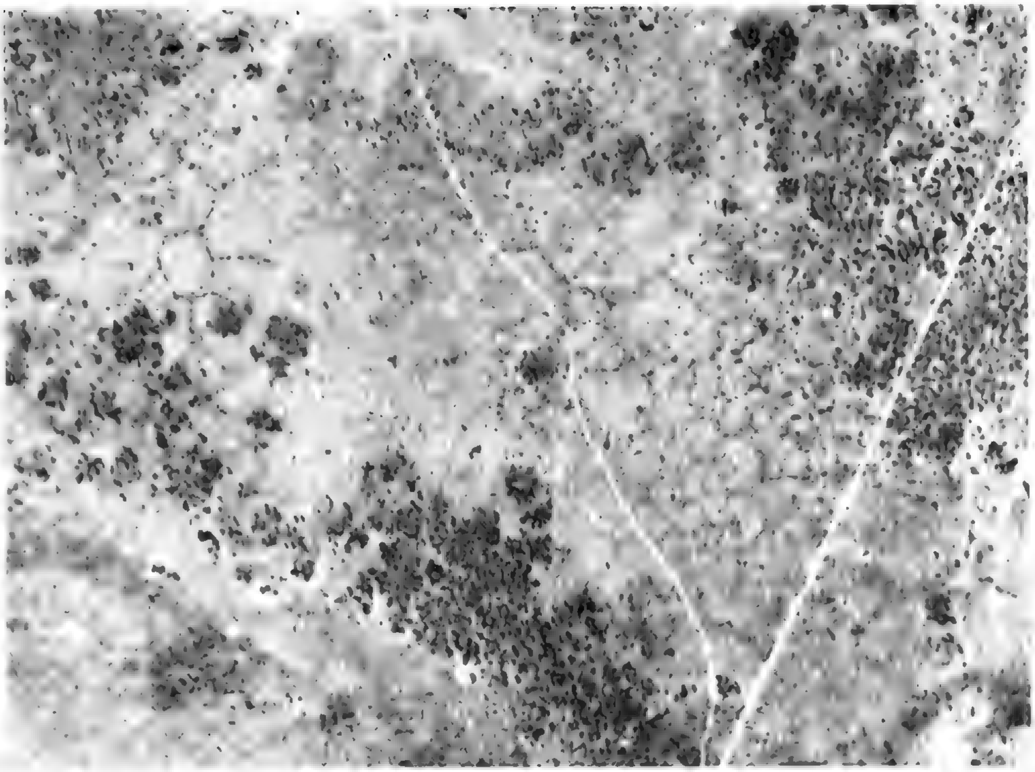

Fig. 1 (*Top*) Aerial photograph showing hexagonal patterned ground; scale approx. 6 cm. to 1 km. (Courtesy S.A. Dept. of Lands.)

Fig. 2 (*Above*) Well formed straight-sided channel.

Fig. 3 (*Left*) Section through gutter showing narrow trench infilled with darker material. [The hollow below the trench is an artefact produced by water lying in the soil pit.]

CONTRIBUTIONS TO THE RECORDS OF EUCALYPTUS L'HERITIER IN SOUTH AUSTRALIA

BY *C. D. BOOMSMA*

Summary

The nomenclature of three species of *Eucalyptus-E. incrassata* Labill. *E. odorata* Behr ex Schldl. and *E. pyriformis* Turcz., is discussed while alterations are described to the recorded occurrence of another five species.

CONTRIBUTIONS TO THE RECORDS OF *EUCALYPTUS* L'HERITIER IN SOUTH AUSTRALIA

by C. D. BOOMSMA*

[Read 8 May 1969]

SUMMARY

The nomenclature of three species of *Eucalyptus*—*E. incrassata* Labill. *E. odorata* Behr ex Schldl. and *E. pyriformis* Turcz., is discussed while alterations are described to the recorded occurrence of another five species.

INTRODUCTION

With such a large genus of six hundred species it is expected that nomenclatural changes will be proposed from time to time. The likelihood of this happening is increased if the *holotype* is relatively imperfect or inaccessible when it is located overseas. In each of the three species in which nomenclatural changes are proposed, difficulty was being experienced in identifying specimens with current floras.

Although the type specimen of only one of the three species was seen, a good photograph was obtained of the second species, both by courtesy of Dr. H. Eichler of the State Herbarium. Mr. J. H. Willis of the National Herbarium, Melbourne, in a personal communication reported on the third species, that he had "looked up the type material of Mueller's *E. youngiana* from Ooldea and Victoria Spring, and it corresponds perfectly to this squat fruited eastern plant".

This is in agreement with Mr. R. Royce and Mr. P. Wilson of the Perth Herbarium who jointly examined the published descriptions of *E. pyriformis* Turcz., *E. erythrocalyx* Oldf. & F. Muell. ex F. Muell. and *E. pyriformis* var. *elongata* J. H. Maiden.

They consider that these are conspecific which is supported by the fact that the taxon with the tapered fruit is endemic to Western Australia.

1. *Eucalyptus incrassata* Labill. in Nov. Holl. P. ii., 12, t.150 (1806).
   Eucalyptus costata F. Muell. ex F. Muell. Trans. Vic. Inst. 33 (1855).
   Eucalyptus incrassata var. *costata* F. Muell. N. T. Burbidge. Trans. Roy. Soc. S. Aust. 71: 150 (1947).

The puzzling feature in the original description is the omission of reference to ridges and in the somewhat schematic illustration which accompanied it. The pertinent part of the description in which no reference to ridges occurs is "calyx turbinatus, subangulatus, germini adnatus, ultra productus, subcampanulatus, operculum coriaceni". This can be translated as "calyx turbinate, subangular, joined to the ovary and extends beyond. Operculum leathery."

During a thirty year period a diligent search in the field in South Australia has failed to locate a significant population with smooth fruits. It is not surprising then that there is a formidable number of specimens with costate fruits in both the Perth and Adelaide Herbariums. This situation could be resolved only by an inspection of the type. Dr. Hj. Eichler, Keeper of the State Herbarium of South Australia, fortunately obtained a photograph of the type with an annotation by the Director of the Florence Herbarium that the handwritten label agreed with the handwriting of the author, Labillardière.

* Woods and Forests Dept., Adelaide.

The type locality is "Nova Hollandia, ora austro-occidentalis" or south west coast of Australia. This agrees with the fact that Labillardière landed at Esperance Bay along the southern coast of Western Australia during December 1792. A full account appears in "Land Flora, The Archipelago of the Recherche" J. H. Willis Aust. Geog. Soc. Rept. 1/3, 3-4, (1953).

A confirmatory annotation by the Director of the Florence Herbarium refers to the presence of small ridges on the torus and these can be seen quite clearly in the enlargement, plate 2. The occasional collections that can be made from individuals with only faint ridges to almost smooth is well within the range of variability reasonably expected where the bulk of individuals have fruits which are firmly ridged.

It is considered then that there is adequate support for the exclusion of consideration of a smooth-fruited form *E. incrassata* Labill., *sensu strictu*, and the erection of two varieties.

E. incrassata Labill. var. *incrassata.*

E. incrassata var. *angulosa* (Schau.) Benth.

The relationship between the varieties can be quite close as intergrades occur between the somewhat smaller, less ridged and sculptured fruits of var. *incrassata* to the heavily ridged with sharp edges or corrugated thick walls of the usually larger fruits of var. *angulosa* Benth.

Selected specimens of *E. incrassata* var. *incrassata* in AD include:—

Eyre Peninsula M. E. Phillips 1965 Cleve; R. L. Specht 1950 Section 21 Hundred Murlong, 105 km north of Port Lincoln; H. C. Robjohn 1967 Sir Joseph Banks group of islands; J. B. Cleland 1963 Lock.

Yorke Peninsula R. L. Specht 1950 Port Julia.

Central District N. W. Donner 1963 Reeves Plains.

Murray Mallee J. W. Green 1950 Moorlands; R. L. Specht 1960 Hundred Pecbinga 80 km S.S.E. of Renmark; E. H. Ising 1958 Murray Bridge; R. L. Specht 1960 Wanbi Research Centre.

South East D. Hunt 1962 Bordertown.

Western Australia R. Parsons 1967 Madura.

Selected specimens from Perth Herbarium.

C. A. Gardner 1924 Hopetoun; R. S. Royce 1956 West Cape Howe; A. Main 1960 along track to Streich Mound; A. S. George 1964 Porongorup Range.

Selected specimens of *E. incrassata* var. *angulosa* in AD include:—

Eyre Peninsula, D. J. E. Whibley 1958 Boston Point; K. D. Rohrlach 1961 West Point; D. J. E. Whibley 1958 Yeelanna; J. B. Cleland 1964 Wanilla.

Lakes of Lower Murray, R. D. Williams 1959 Meningie; C. D. Boomsma 1967 Goolwa.

Southern Districts, R. Schodde, Waitpinga.

2. *E. normantonensis* Maiden & Cambage.

This species was recorded for South Australia in the supplement to "J. M. Black's Flora" by Hj. Eichler on p. 236 on the basis of a single specimen J. B. Cleland 1933 Ernabella, Musgrave Ranges. The previous record of this species was qualified by:

> "the assumption that the specimen recorded by Black (1952) as *E. largiflorens* var. *xanthophylla* was correctly determined. Its leaves are rather broad (2 cm)."

On inspection, the specimen was seen to have wide thick coriaceous leaves and was referred to *E. intertexta forma*, R. T. Baker.

The position now is that the record for this species should be cancelled for South Australia and it is unlikely to be reinstated, as this species is typical of the northern tropical regions.

3. *E. odorata* Behr ex Schldl.

This is a preliminary note resulting from an examination of the *holotype* HAL 17751, but in the absence of the types of any of the described varieties. The rather vague locality of the *holotype* was "Aldenhoven Estate" and a search of the old land title of the estate showed that it consisted of four parcels of land in the Barossa Valley distributed from Angaston to Fords, a distance of 20 miles. An inspection of each parcel showed that the property at Angaston still supports exclusively an uncleared woodland of *E. camaldulensis*, whilst *E. odorata* still occurs either on or nearby the other three. Specimens recently collected from these compare favourably with the *holotype*.

A striking difference in maximum leaf width between this and the wide leaved specimens from the western slopes of the foothills of the Mount Lofty Ranges was recorded without further comment by Boomsma, Trans. Roy. Soc. S. Aust. 83: 197 (1960). An extension to the occurrence of the wide leaved taxon is now recorded from Bordertown to Western Flat and Wolseley in the South East.

A comparison of the maximum leaf width per mounted sheet in the Woods and Forests Department Herbarium, South Australia, is as follows:—

	No. of specimens	*Maximum Width mm*
Wide leaved specimens	27	32 ± 1
Typical leaved specimens	29	18 ± 2
Narrow leaved specimens	33	12 ± 1

It would appear that the striking difference of width of the wide leaved specimens in conjunction with its comparatively restricted field distribution justifies the recognition of a varietal status, but the type specimens of other described varieties would be necessary to resolve the situation.

4. *E. pachyphylla* F. Muell.

A single definite collection of this stunted mallee species has been made by R. B. Major in 1966 on a silcrete rise during a geological survey in the Victoria Desert at Long. 129° 24′ E. Lat. 27° 56′ S. The specimen is lodged in the Woods and Forests Department Herbarium, South Australia.

5. *E. pileata* Blakely.

Mr. L. A. S. Johnson in a personal communication to Mr. D. Symon points out that this species has a characteristic pileate bud and that South Australian material is not in agreement with that from the type locality in Western Australia. Specimens of South Australian origin were then forwarded to Sydney Herbarium in early 1966 for determination.

6. *E. pyriformis* Turcz. Bull. Soc. Nat. Moscow xxii., pt. 2, 22 (1849).
E. erythrocalyx Oldf. & F. Muell. ex F. Muell. (1860).
E. pyriformis var. *elongata* Maiden (1914).

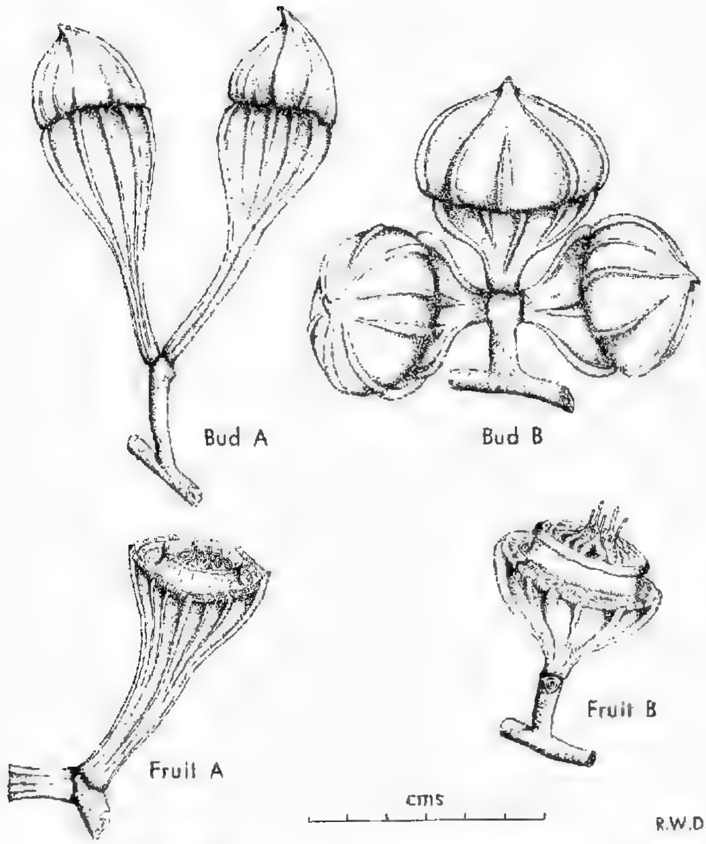

Fig 1. A *Eucalyptus pyriformis* *subspecies pyriformis* Turcz   B *Eucalyptus pyriformis* *subspecies youngiana* (F.v.Muell.) C. Boom

For some time two superficially similar large fruited mallees have been recognised as *E. pyriformis* var. *elongata* Maiden, and *E. pyriformis* Turcz., respectively.

That two taxa are justified is suggested by the constant elongate torus, with shallow furrows tapering into the long pedicel in the one from Western Australia, contrasting with the abrupt short pedicel to the squat torus with deep furrows, in the one from South Australia.

Mr. P. Wilson, Botanist, Perth Herbarium (private communication) has pointed out that specimens from the north of Perth, in particular from Wongan Hills, have long pedicels fully in agreement with that of the original description. Further, in a letter by the collector of the type, Drummond, to Hooker and published in 1853 in the Journal of Botany by Hooker, the locality of Wongan Hills is mentioned and could therefore constitute the type locality. Mr. P. Wilson records in a private communication "The original description of *E. erythrocalyx* agrees with that of the material found in the Wongan Hills and Three Springs areas and is probably conspecific and convarietal with *E. pyriformis*."

It is interesting to note that so far no record has been made of a specimen from South Australia similar to that of the original description of *E. pyriformis*. Instead there is an abundance of the squat budded form which extends well into inland Western Australia at Laverton, as well as Israelite Bay on the Great

Australian Bight. It is known for certain that a collection of the squat budded form MEL 31296 was made by Mr. Jess Young, a member of Giles 4th expedition in 1875, from a locality given as Queen Victoria Spring, Western Australia, which is two hundred miles inland at 30° 25′ S. Lat. and 123° 35′ E. Long. Less than one hundred miles inland at Ooldea in South Australia a second collection MEL 31297 was made and the label is in the handwriting of Mrs. Ann Richards.

The label reads as follows: "A few specimens of Oldia large flowering mallee. I begged these for you, but they are such poor things I fear they will be of no use.

"Should we be here next winter, will try to get some good specimens."

Mr. J. H. Willis points out (in a personal communication) that the specimen MEL 31297 was probably collected by Police Trooper Richards, her husband, who acted as a guide for Giles in March 1875 en route to Ooldea.

The actual year of collection is uncertain, however, as Richards had been to Ooldea previously.

In considering the shape of the buds of the two taxa, one tapered, the other squat, coupled with the fact that the main occurrence of each taxon is geographically distinct, a subspecific rank is proposed.

E. pyriformis Turcz. subsp. *pyriformis*.

E. pyriformis subsp. *youngiana* (F. Muell.) C. Boom. basionym *E. youngiana* F. Muell. Fragm. Phyt. Austral. x., 5 (1876).

The selected specimens of *E. pyriformis* subsp. *youngiana* in the AD were all collected from the far western arid region of South Australia. They include:— N. B. Tindale 1934 Ooldea; D. Symon 1962 Cheesman Peak; T. R. N. Lothian 1964 43 km. west of Tallaringa Well; 1967 10 km. west of Emu; O. H. Turner 1965 Maralinga. The illustrations were made from AD 96749222, Ooldea; and 96801936 Cult. Waite Agric. Res. Inst.

7. *E. striaticalyx* W. F. Fitzg. was identified by L. A. S. Johnson in 1965 as occurring in South Australia from specimens forwarded to him by D. Symon. It was recorded in corrigenda and addenda to the Supplement to "J. M. Black's Flora of South Australia" by Hj. Eichler, 1966. Both before and since then, it has been collected sparingly in several dispersed localities giving it a wide potential distribution, stretching from the Transcontinental Railway northwards to the Musgrave Ranges, and perhaps beyond, and westwards to Western Australia. In a personal communication to Mr. D. Symon, in Sept. 1965, L. A. S. Johnson remarks that "this is a new record for South Australia and a most interesting extension of its range. This species, thought for a long time to be rare and confined to the Cue-Nannine area in Western Australia, has in recent years been found in several places as far as 59 miles north of Kalgoorlie."

The type locality as recorded by W. V. Fitzgerald, is Milly's Soak four miles east of Nannine. With permanent water within root reach it is not surprising that the associated trees are *E. microtheca* and *E. camaldulensis*, and that it is able to reach a height of 10 to 12 metres, and a diameter of 45 cm. In South Australia it is reduced to a mallee, or small tree, of a proportionate size to the accompanying vegetation such as *Acacia aneura*, *E. pyriformis* subsp. *youngiana*, *E. terminalis*, *Pittosporum phylliraeoides*, and *Triodia* sp.

Selected specimens:—

ADW Symon 1965, Commonwealth Hill Station; Woods & Forests Department S.A., J. Johnson 1955, Musgrave Ranges; O. H. Turner 1960, Maralinga; J. Johnson 1966, Loch Arline Outstation (Commonwealth Hill Station); R. B. Major 1966, Long. 129° 30′ E., Lat. 27° 58′ S.

8. *E. viridis* R. T. Baker.

The occurrence of this species in South Australia has been either queried or confused with *E. odorata* var. *angustifolia* Blakely, but a number of recent collections have been made of it, all from the one large elevated region of the North East Flinders Ranges and Mainwater Pound, Gammon Ranges. Itemised localities of recent collections include: Mainwater Pound, J. Johnson; and Mt. Patawarta, K. Mack; S.A. Woods and Forests Department Herbarium, and Mt. McKinley at 3000′ altitude, D. Symon, ADW 31 293.

The identification has been confirmed by J. H. Willis, of the National Herbarium of Victoria despite the dull to subglaucous mature foliage. Fortunately the linear-lanceolate leaves of seedlings are in good agreement with the species description.

ACKNOWLEDGEMENTS

The assistance is gratefully acknowledged of Dr. Hj. Eichler, for obtaining the loan of the type specimens; Mr. D. Hester, for reliable translations of the original Latin descriptions of *E. incrassata* and *E. odorata*; and Mr. B. H. Bednall, Conservator of Forests, who made the services of Mr. R. Davies available for the illustrations. Mr. J. H. Willis, Mr. R. Royce and Mr. P. Wilson kindly gave critical opinions of the proposed nomenclatural changes.

PLATE 1

The type sheet of *Eucalyptus incrassata* Labill. var. *incrassata* showing the original collector's label.

PLATE 2

An enlargement of the central portion of the left-hand side specimen on Plate 1 showing the ridges on the torus of the buds and young fruit.

A NEW SPECIES OF TREE FROG (HYLA) FROM PAPUA

*BY J. I. MENZIES**

Summary

A collection of frogs from Efogi in the Owen Stanley Mountains includes a tree frog (Hyla) with a combination of characters unlike that of any other Papuan species described in the recent monograph by Tyler (1968). With reference to the pronounced dermal spike on the snout, the new species is named.

A NEW SPECIES OF TREE FROG (*HYLA*) FROM PAPUA

by J. I. MENZIES*

(*Communicated by M. J. Tyler*)

[Read 10 July 1969]

A collection of frogs from Efogi in the Owen Stanley Mountains includes a tree frog (*Hyla*) with a combination of characters unlike that of any other Papuan species described in the recent monograph by Tyler (1968).

With reference to the pronounced dermal spike on the snout, the new species is named

Hyla prora† new species.

Holotype. University of Papua and New Guinea No. 1015, an adult male collected near Efogi by the writer on December 12, 1968. Altitude 3,800′; location 147° 38′ E.; 9° 9′ S. and approximately 37 miles north-east of Port Moresby.

Paratypes. There are four paratypes, all adult males, collected at the type locality with the holotype: University of Papua and New Guinea Nos. 1018 and 1019; South Australian Museum Nos. R. 10410, 10411.

Diagnosis. A medium-sized arboreal *Hyla* with fully webbed fingers, a pronounced fleshy spike on the end of the snout and cryptic, lichen-like dorsal markings.

Description of the holotype

Habitus slender, and flattened, the outline at rest irregular and extremely cryptic (Fig. 1A and 1B).

Dimensions: body length (S-V), from apex of rostral spine to cloaca 39·3 mm.; tibial length (TL) 19·0 mm.; head length (HL), including spine 13·5 mm.; head width (HW) 11·4 mm.; eye to nostril distance (E-N) 2·9 mm.; internarial distance (IN) 4·5 mm.; eye diameter 3·7 mm.; tympanic diameter 1·9 mm.

The head is flattened and longer than broad (HL/HW 1·19) and slightly more than one-third of the body length (HL/S-V 0·34). The snout bears an acutely tapering fleshy spine, forwardly directed and sharply demarcated from the head. The spine is 2·3 mm. long and 1·4 mm. wide at the base. The nostrils are completely lateral and set in depressions on raised tubercles. The eye to nostril distance is greater than that between the nostril and the apex of the rostral spine but less than the internarial distance (E-N/IN 0·644). The canthus rostralis is strongly curved but not well defined due to the warty nature of the skin. The loreal region is oblique and slightly concave. The eye is small, approximately one and three quarters times its distance from the nostril. The tympanum is small and ill-defined being completely covered with skin. Its upper one-third is concealed by the supratympanic fold of skin but the lower rim is prominent. The tympanic diameter is approximately one-half that of the eye. The vomerine teeth are in two very small groups level with the mid-line of the choanae. Their

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† From the Greek *prora*, the prow of a ship.

distance from the choanae is about twice their own width. The inferior margin of the lower jaw bears a row of prominent irregular dermal flaps and tubercles.

The fingers are fairly long and extensively webbed and have large terminal discs. The web extends to the base of the discs on digits 2 and 4 and to the penultimate articulation on digit 3. Fingers in decreasing order of length are $3 > 4 > 2 > 1$. There is an elongate moderately pigmented nuptial pad (Fig. 1C).

The hind limbs are fairly short (TL/S-V 0·483), toes in decreasing order of length are $4 > 5 = 3 > 2 > 1$. The web extends to the base of the disc on the 5th digit, to the penultimate articulation on digits 2 and 4 and to the pre-penultimate articulation on digit 3, continuing as a narrow fringe to the base of the disc. There is a moderate inner metatarsal tubercle but no outer one. The sub-articular tubercles are poorly developed.

The skin on the dorsal surface is entirely and irregularly covered with low, rounded tubercles. A fold of skin commences at the posterior corner of the eye, passes across the tympanum, over the insertion of the fore-limb and continues to the groin. The dorsal skin of the fore-limbs is similar to that of the body. There is a pronounced, irregularly crenulated fringe from the posterior side of the elbow to the disc of the 4th digit. A similarly crenulated fringe runs down the posterior side of the hind-limb, from the middle of the tibial section to the disc of the 5th digit. A large triangular dermal flap at the heel forms part of this fringe. Two large, semi-circular, warty flaps are situated ventro-lateral to the cloaca.

The ventral surface is entirely and irregularly tubercular with the exception of the fore-limbs and the hind-limbs, distal to the knees, which are smooth. There is a gular vocal sac opening from the buccal cavity on each side of the tongue but the skin of the gular region is not markedly different from elsewhere.

Colour in life

The dorsal coloration was variable and extremely cryptic, consisting of a mixture of greys, greenish-greys and ochres forming the ground colour with smaller, scattered blotches of darker browns and blacks, the whole giving an impression of lichens on dead wood. Sometimes a faint hour-glass mark appeared, commencing between the eyes and fading out before the cloaca. The visible surfaces of the fore- and hind-limbs had darker and lighter cross bands.

The colour of the margin of the lower jaw was the same as the dorsal surface with a few black spots extending on to the gular region. The rest of the ventral surface was an immaculate white, except in the region of the groins.

The concealed surfaces of the hind limbs and the sides of the body from groin to axilla were brownish-purple with scattered white spots. This colour extended ventrally from the groins to meet in the mid-line.

The iris was gold with two lateral dark blotches extending the line of the horizontal pupil.

Colour in alcohol

The dorsal colour is basically grey with a slight bluish tinge. The hour-glass mark is discernible and brownish in the centre. There are scattered, irregular darker blotches and faint transverse bars on the limbs. The coloration of the concealed portions of limbs and body is little different from that in life.

Variation

The five type specimens form a uniform group. The head is consistently longer than broad (HL/HW 1·060 to 1·195) and may be slightly more, or slightly less, than one-third of the body length (HL/S-V 0·318 to 0·357). The

E-N/IN ratio varies from 0·511 to 0·708 and the eye diameter is always less than the internarial distance. The body length varies from 38·1 mm. to 41·2 mm.

The basic coloration is the same in all specimens but the irregularity of the pattern makes no two exactly alike. The hour-glass mark varies in intensity and the dark colour of the groins varies in extent. In the holotype the groin patches meet broadly in the mid-ventral line, in one paratype they meet narrowly, in another they fail to meet at all.

The crenulated fringes on the limbs and the dermal lappets on the margin of the lower jaw vary in size and distribution.

The nuptial pads vary slightly in shape but all consist of a long, narrow, proximal portion and a shorter, wider, distal part.

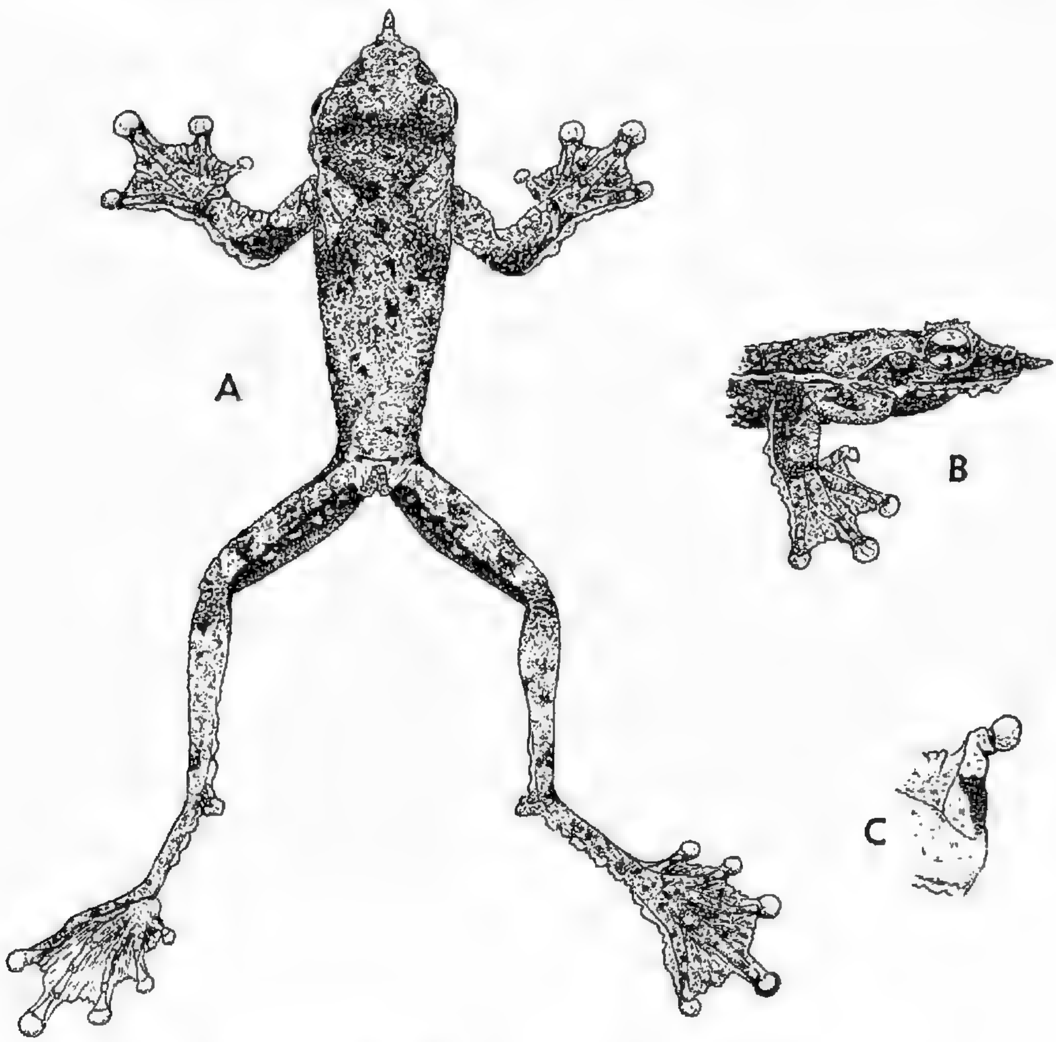

Fig. 1 *Hyla prora*, new species, holotype.
A. dorsal view with left hind foot turned to show ventral surface.
B. lateral view, head and fore limb.
C. left thumb and nuptial pad.

Voice

The call consists of 3 to 10 figures at approximately one-third of a second intervals, the figures not sharply cut off but fading into the succeeding ones. The frequency intensity maximum is 2·2 Kcs. and the acoustic impression is a faint, wavering bleat. A more detailed analysis of the call, together with that of other Papuan frogs, will be published in due course.

Habitat

The holotype and the four paratypes were collected at night as they called from low bushes overhanging a small pond, about half a mile from Efogi village. The natural vegetation of the region is dense rain forest on steep-sided valleys but there are considerable areas under cultivation and patches of coarse grass (kunai) where the forest has failed to regenerate after clearing. The pond was on the boundary between such a kunai patch and the forest, a few yards from a running stream.

The Owen Stanley Mountains are the most easterly of the central ranges of the New Guinea mainland. They rise to over 12,000′.

Comparison with other species

The presence of a distinct rostral spine sets the new species apart from all other Papuan *Hyla*, the nearest approach to this condition being seen in *H. spinifera* which has an extremely prominent snout and is also a tubercular montane species. However, the hands of *spinifera* are unwebbed so that further comparison is unnecessary.

The only other Papuan *Hyla* with fully webbed hands are *amboinensis*, *aruensis*, *darlingtoni* (some individuals), *eucnemis*, *graminea* and *multiplica* but these species all have rounded snouts. Additional points of comparison are as follows. *Hyla amboinensis* is a lowland species, generally larger; it has a loud giggling call that can be heard one hundred yards distant. *Hyla aruensis* has a smooth dorsal skin and a uniform green colour; *H. darlingtoni* is a montane species but the backs of its thighs are vividly marked black and yellow; *H. eucnemis* is a submontane species but its nostrils are closer together (E-N/IN 1·0 to 1·5 compared to 0·5 to 0·7) and its nuptial pad is a different shape; *H. graminea* is a much larger plain green species; *H. multiplica* is another montane species but the colour is different (green in life) and the dermal folds on the limbs are not nearly so prominent.

ACKNOWLEDGEMENT

I wish to thank Mr. M. J. Tyler of the South Australian Museum for his critical reading of the manuscript and for examining two of the paratypes.

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Tyler, M. J. (1968). Papuan hylid frogs of the genus *Hyla*. Zool. Verh., Leiden. (96): 1-203.

LITHOLOGY AND DISTRIBUTION OF THE OBSERVATORY HILL BEDS, EASTERN OFFICER BASIN

*BY H. WOPFNER**

Summary

The new term OBSERVATORY HILL BEDS is proposed for a sedimentary sequence exposed along the southern and eastern margin of the South Australian portion of the Officer Basin. The type section is located at 28° 58•2' S. latitude and 131° 59•7' E. longitude. The sequence comprises red, green and grey micaceous siltstones and silty shales, frequently calcareous; brown, fine to medium grained greywacke, and thin carbonate-chert beds. The main characteristics are high contents of K-feldspar in the elastics, extremely thin parallel bedding of the greywacke and concentric, multicoloured chert nodules and chert breccias associated with the carbonates. Mud cracks are common.

The sediments were formed during a period of tectonic instability and were deposited in a shallow water, medium to low energy environment. Mildly evaporitic conditions are indicated by the presence of beds of gypsum and chemically precipitated carbonates.

No fossils have been found in these sediments but contact-relationships with underlying and overlying sediments indicate that the Observatory Hill Beds are of middle to late Cambrian age. It is suggested that they were deposited during the period of tectonic instability in which the sediments of the Lake Frome Group were laid down.

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by H. Wopfner*

[Read 13 November 1969]

ABSTRACT

The new term Observatory Hill Beds is proposed for a sedimentary sequence exposed along the southern and eastern margin of the South Australian portion of the Officer Basin. The type section is located at 28° 58·2′ S. latitude and 131° 59·7′ E. longitude. The sequence comprises red, green and grey micaceous siltstones and silty shales, frequently calcareous; brown, fine to medium grained greywacke, and thin carbonate-chert beds. The main characteristics are high contents of K-feldspar in the clastics, extremely thin parallel bedding of the greywacke and concentric, multicoloured chert nodules and chert breccias associated with the carbonates. Mud cracks are common.

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INTRODUCTION

The Officer Basin is truly one of the "last frontiers" in South Australian geology. Nowhere else in this State is there an area of comparable size about which so little is known. The nature of the basin's sedimentary fill, its stratigraphy and its structure are still largely unresolved and most of the few data now available were produced by oil exploration work carried out by Exoil Pty. Ltd., Continental Oil Co. of Australia, and by the South Australian Geological Survey over the past 6 years.

The first subsurface data were obtained however during an intensive groundwater search for the Maralinga and Emu Field atomic testing grounds (Barnes, 1956) carried out by the South Australian Geological Survey prior to the commencement of oil search in that region.

Within the South Australian part of the Officer Basin 2 deep oil exploration wells and 2 shallow stratigraphic tests have been drilled so far, but none of these wells penetrated the full sedimentary thickness and only one of them (Continental Sun, Exoil Munyarai No. 1) produced tangible palaeontological evidence as to the age of the basin-fill.

Similarly there is an almost complete lack of formally defined stratigraphic units. The aim of the present paper is to define and describe the Observatory Hill Beds, a characteristic sediment-sequence which has been observed by the author over a wide area of the eastern Officer Basin.

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Most of the field-data were gathered during 1966, when the Petroleum Division of the South Australian Geological Survey conducted a seismograph survey between Emu Field and the Officer Creek, and during a visit to a contract seismic crew operating in the vicinity of Serpentine Lake, near the Western Australian Border.

REGIONAL SETTING

The Officer Basin is an arcuate shaped basin, extending from about 123° east longitude in Western Australia to 134° east in South Australia (Fig. 1). The northern margin of the basin is formed by the igneous and metamorphic complex of the Musgrave Block. The southern and south-eastern limits are ill-defined as the older sediments of the Officer Basin are, at least in parts, overlapped by the Mesozoic-Tertiary sequence of the Eucla Basin and the Permian-Mesozoic of the Arckaringa Basin.

Geophysical data obtained from the South Australian portion of the Officer Basin in recent years, show a deep trough adjacent to the Musgrave Block, with sediment accumulations in excess of 18,000 feet (Moorcroft, 1969). To the south of this trough the basin shelves gradually till, in the vicinity of Maralinga, sedimentary thickness is reduced to some 1,700 feet (Barnes, 1956; Ludbrook, 1961).

The basin's inception appears to date back into late Precambrian time, although in the eastern Officer Basin the major part of sedimentary contribution

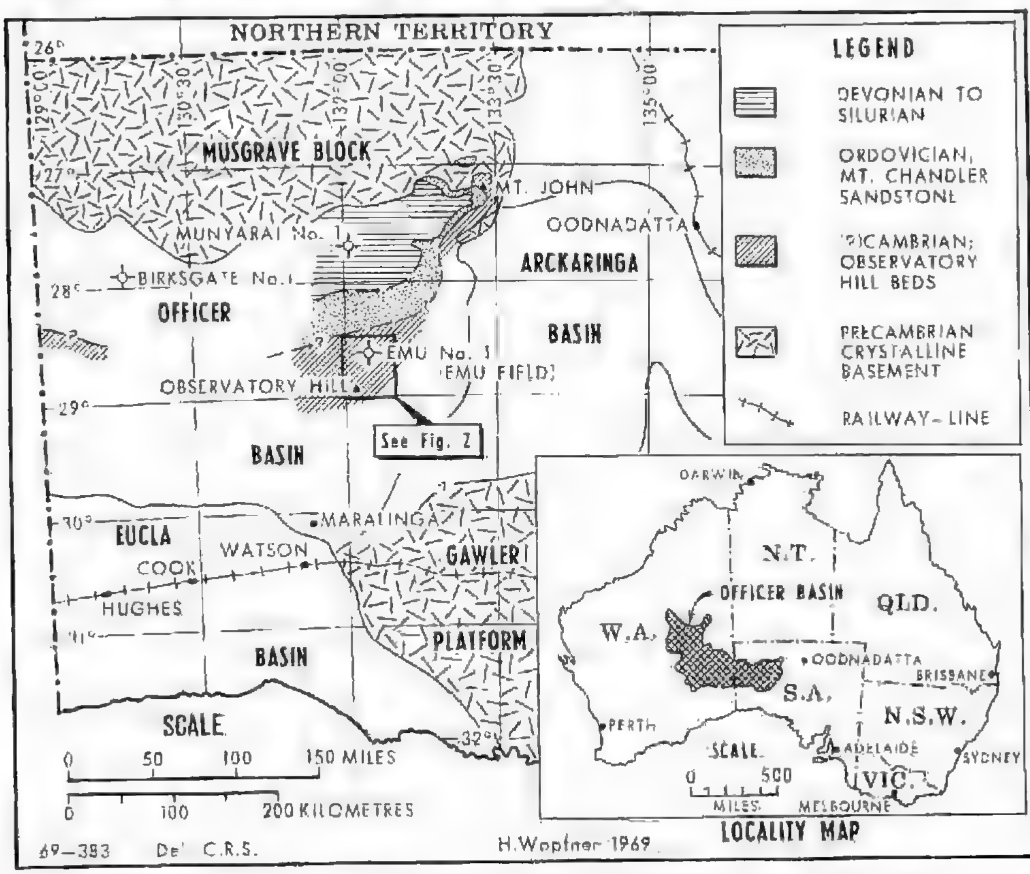

Fig. 1. Locality plan and generalised surface geology of eastern Officer Basin.

was received between the Cambrian and the late Devonian or early Carboniferous (Krieg, in press). Outcrops of the younger sediments occur near the centre of the trough whilst exposures of successively older sediments appear towards the southern margin of the basin (Fig. 1). Overlap of Ordovician sediments is reported by Krieg (in press).

The area occupied by the Officer Basin is synonymous with the Great Victoria Desert, which extends from the Everard-Musgrave and Mann Ranges in the north to the Nullarbor Plain in the south. The whole region is monotonously covered by latitudinally trending, red sand dunes, now thickly vegetated by mulga-scrub. Occasional stands of tall black oaks (*Casuarina cristata*) thrive where Pleistocene carbonates underlie the desert floor. The area is uninhabited by white men and even aborigines venture into it only on rare occasions.

The floor of the Great Victoria Desert exhibits a slight, but nevertheless distinctive south-tilt with a gradual decrease of surface elevation from around 1,400 feet in the north to about 400 feet near Maralinga, an average gradient of 5 feet per mile.

Remnants of Pleistocene river systems, once extending from the ranges along the northern basin margin down to the Nullarbor Plain, but now disrupted and choked by the desert dunes, may still be recognised in meandering salt pans such as Serpentine Lakes. In some instances the rivers have cut steep-sided channels into the old land surface. Remnants of these embankments now form low escarpments around some of the playa lakes and afford good exposures of the basin sediments (Wopfner, 1967). Outcrops occur also on the slopes of silcrete-covered mesas, but this landform is very rare.

OBSERVATORY HILL BEDS

The Observatory Hill Beds as defined herein comprise the sedimentary sequence of multicoloured clastics and carbonates which are exposed at, and in the vicinity of Observatory Hill, a low, but prominent mesa, situated 86 miles north of Maralinga on the track to Emu Field (Figs. 1 and 2). The name which has been derived from the same locality, was first used in an informal sense by Wopfner (1967).

The term "Emu Sandstone" used informally by Exoil Pty. Ltd. and Continental Oil Co. of Aust. Ltd. in unpublished company reports in reference to sediments in the vicinity of Emu Field is rejected as the prefix Emu is used already in Emu Bay Shale, defined by Daily (1956).

The Observatory Hill Beds are identified by characteristic lithologies, particularly carbonates with chert breccias and multicoloured, concretionary chert nodules, and by laminated arkoses, greywacke and feldspathic siltstones.

Type Locality

Observatory Hill and its surroundings were selected as type locality for their good exposures and because all of the typical lithologies displayed by this formation may be observed in close proximity to each other. At Observatory Hill, however, the sediments are partly altered by the deep weathering profile of the quartzose silcrete (duricrust) which caps the mesa. The type section was therefore chosen 4 miles west of Observatory Hill, where a low escarpment along the western shore of a playa lake displays an excellent section with almost 100% exposure of the flat lying sediments (Fig. 2 and Plate 1/1).

Along the foot of this escarpment there is a great variety of remarkable aboriginal stone arrangements, consisting of long rows of stone pyramids presumably associated with ceremonial rituals. The stone arrangements of this

ceremonial site, sometimes referred to as "Stonehenge" have been described in some detail by Campbell and Hossfeld (1966).

The type section is easily accessible via an ill-defined track which turns off the Maralinga track 4 miles south-west of Observatory Hill.

Lithology

The sediments exposed at the type section of the Observatory Hill Beds, although dominantly a clastic sequence, display a variety of rocks, diversified by colour, grain size and the amount of chemically precipitated material. It is the combination of these various rock types in one depositional sequence plus certain textural and mineralogical trends which are so characteristic of the Observatory Hill Beds and identify them as a stratigraphic unit.

In the type section (Fig. 3), the grain sizes of the clastic sediments range from shale ($< 0{\cdot}03$ mm.) to fine-grained sand ($0{\cdot}25$ mm.) and their colours vary between bluish grey, green, tan, maroon and brown. Maroon and green mottling is also common.

Within the lower two-thirds of the section, the clastics are mainly shales or siltstones. They are generally well bedded, fissile or splintery and are nearly always micaceous and some exhibit well developed mud cracks (Plate 2c). The clastics are also often calcareous and thin bands and lenses of limestones, dolomites and cherts, are commonly interspersed throughout this part of the sequence (Fig. 3).

These chert-carbonate associations not only provide one of the typical lithologies by which the Observatory Hill Beds may be recognised in widely separated areas but are also an important environmental indicator. The chert generally occurs in thin lenticles or in concentric concretions of ellipsoidal or botryoidal shapes, with an average diameter of 20 to 30 mm. (Plate 2b). Angular pieces of chert sometimes form the cores of these concretions. The individual concentric shells of these concretions display a variety of colours such as black, white, grey and hues of red which lends them a most attractive appearance when freshly broken or cut. As their resistance to weathering is considerably greater than the remaining sediments they are preserved even in deeply weathered and altered profiles (Wopfner, 1968) or remain as lag along the foot of debris covered slopes (e.g. Observatory Hill). Other typical chert-carbonate associations are chert-breccia or micro-breccia whereby angular pieces of chert are embedded in a carbonate matrix. Sometimes these chert-breccias can be traced laterally into undisturbed chert bands, clearly demonstrating the penecontemporaneous nature of these breccias.

The carbonates themselves are mainly crystalline or micro-crystalline-micritic and intraclasts are generally rare in the clean varieties. Some of the carbonates are thinly banded, with alternating bands of limestone, dolomite and chert (unit 17). Terrigenous clastic material, mainly quartz and some feldspar varies within very wide margins, from very small percentages to equal participation or predominance. Special features of some of these carbonates are inclusions of scapolite (units 3, 4, and 7) and large euhedral grains of red oligoclase albite (unit 7).

Petrographic descriptions of some of the carbonate rocks are given in the appendix and a summary of their composition is shown in Table 1 below.

The top third of the type section is composed of non-calcareous clastics and sediments in the fine sand range ($0{\cdot}25$ to $0{\cdot}125$ mm.) become more abundant. As in the lower parts of the section, the sediments are generally micaceous and feldspathic. The "sandstones" are generally friable to semifriable and they show a high clay content which classifies these sediments as greywacke. Small lithic

TABLE 1

Composition of calcareous sediments from type-section of Observatory Hill Beds and from Emu No. 1 well

Minerals identified	Percent of mineral composition from visual estimates						
	P293/68 Unit 2	P294/68 Unit 3	P292/68 Unit 4	P287/68 Unit 5	P288/68 Unit 7	P289/68 Unit 9	P1/69 Emu No. 1 1105 ft.
Calcite	40—50	30—40	45—50	70—80	40—50	50	30
Dolomite	30—40	50	nil	1—2	2—5	10	nil
Chert	10—20	5—10	40	10—20	nil	nil	nil
Quartz	1—5	5	2—5	10—35	40—50	30—40	30
Feldspar	nil	nil	*	*	1	nil	30—35
Clay	nil	nil	*	*	2—3	5—10	†
Chlorite	nil	nil	*	*	†	1	†
Leucoxene	nil	nil	*	*	†	†	nil
Biotite	†	†	*	*	†	nil	†
Muscovite	†	†	*	*	†	1	†
Tourmaline	†	nil	*	*	†	nil	†
Garnet	nil	nil	*	*	†	nil	nil
Apatite	nil	nil	*	*	†	†	nil
Zircon	†	nil	*	*	†	†	nil
Scapolite	nil	1	5—10	*	†	nil	nil
Opaques	†	1	†	*	†	1—2	2—3

* = not determined † denotes trace-amounts

grains are also common. One of the main features of these sediments is the abundance of detrital K-feldspars which constitute up to 30% of the rocks' composition. Plagioclase feldspars are also present but in much smaller amounts (see Table 2). K-feldspar is either microperthitic as in unit 21 or occurs as microcline

TABLE 2

Composition of arenaceous sediments of Observatory Hill beds

Minerals identified	Percent of mineral composition from visual estimates					
	P 291/68 Unit 21 in Type sect.	P 295/68 4 miles N of Observatory Hill	P 296/68 4 miles S of Emu Field	P 297/68 2 miles S of Emu Field	P 298/68 Emu Field	P 299/68 5 miles E of Serpentine Lake
Quartz	60—70	55—65	60—70	40—50	50	60—70
Plagioclase	2—5	1—3	4—6	1—2	1—2	1—2
K-Feldspar	20	10—20	20—30	10—20	15—20	10—20
Muscovite	2—3	2—3	1—2	1—2	3—5	2—3
Biotite	2	nil	*	nil	*	nil
Chlorite	5	nil	nil	30—40	1—3	20
Clay	5—20	10	0—10		20—35	
Sericite	nil	5—10	5	nil	nil	nil
Tourmaline	*	nil	*	nil	*	*
Zircon	*	*	nil	nil	nil	nil
Clinozoisite	nil	nil	nil	nil	*	nil
Rutile	nil	nil	nil	nil	*	nil
Apatite	nil	*	nil	nil	nil	nil
Opaques	*	nil	1—2	1	*	1

* denotes less than 1 percent

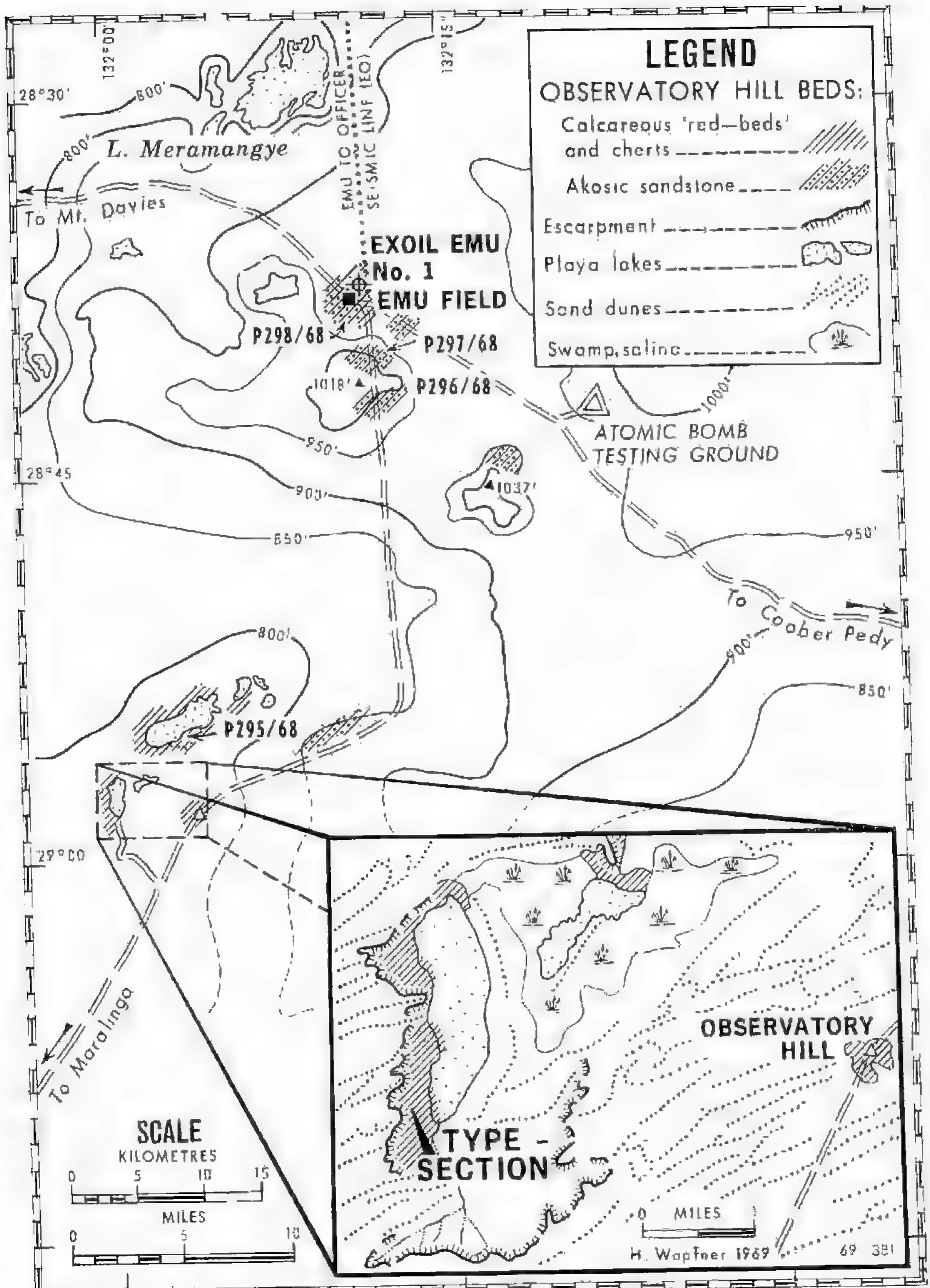

Fig. 2. Type area of Observatory Hill Beds, south-eastern Officer Basin. Contours show surface-elevations in feet. P-numbers refer to petrographic descriptions in the Appendix.

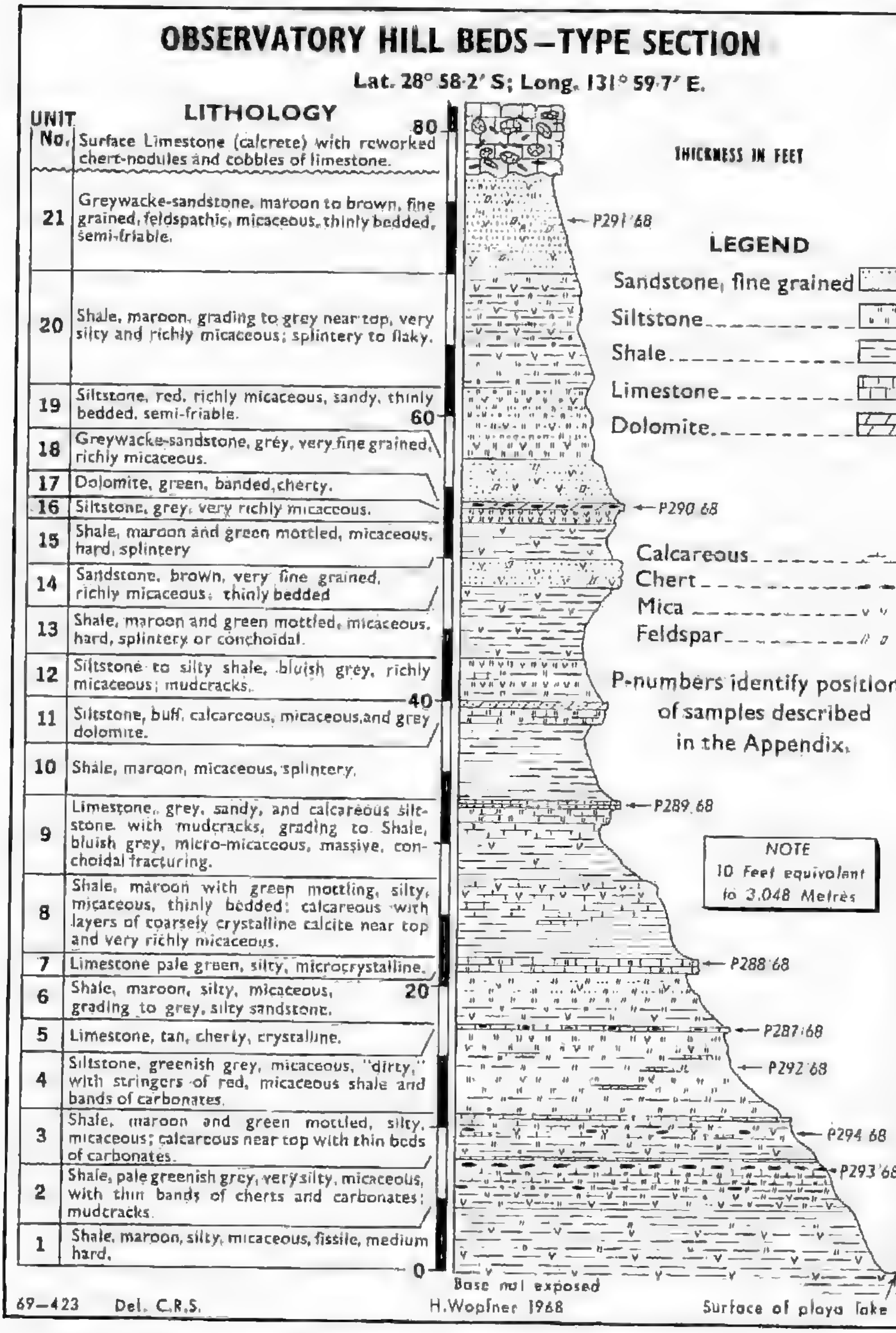

Fig. 3. Type section of Observatory Hill Beds, 4 miles west of Observatory Hill.

or untwinned forms. The greywackes in the type section are thinly bedded or current laminated. A tendency towards small-scale festoon-current bedding is exhibited in unit 21.

To the north-east of the type section exposures of greywacke and arkoses become more important. On the south shore of the large playa lake, situated about 5 miles north-east of the type section (P295/68 in Fig. 2) a brown, clayey arkose interbedded with highly weathered cherty shale is exposed. This arkose exhibits perfect parallel bedding, the individual bed thickness being very evenly in the range of 2 to 4 mm. This thin parallel bedding with high fissility is very typical for most of the fine-grained greywackes and arkoses and is another characteristic feature of the Observatory Hill Beds.

Outcrops in the immediate vicinity of Emu Field consist dominantly of greywackes and clayey arkoses in the size range of fine to medium grained sand (0·50 to 0·12 mm.). The lowest outcrops occur in the west side of the airstrip where they consist of fine to medium grained, thinly current or parallel bedded white greywacke with an average bed thickness of 10 to 15 mm. About a mile south-west of this occurrence and south of the only remaining building of Emu Field Village there is a low escarpment with good exposure of greywacke. The lower 8 feet of this exposure consist again of white, fine to very fine grained, richly micaceous greywacke. This sediment again exhibits the typical, extremely thin parallel bedding with very regular bed thickness of between 1 and 3 mm. In the upper part of this outcrop bed thickness increases to an average of 10 to 15 cm. Sample P298/68 was obtained from this unit. Some powdery gypsum and lenses of alunite occur near the base of this unit. The composition of the greywacke and clayey arkoses exposed near Emu Field Village show the same high K-feldspar content as found in arenaceous sediments within the type section. The white colour of these sediments is almost certainly due to bleaching and chemical weathering within a (?)Cainozoic deep weathering profile. The same process probably was also responsible for the kaolinisation of certain feldspars.

A comparison of the composition of arenites from Emu Field, the type section and other localities is given in Table 2.

The Exoil Well Emu No. 1, drilled to a total depth of 1,370 feet. The well encountered maroon, green and grey siltstones, calcareous siltstones, greywacke, arkoses, and grey cherty limestones (Fig. 4). Small amounts of gypsum were encountered between 1,090 and 1,140 feet and a 1 inch bed of gypsum was recovered in core 4 from 1,105 feet. The strata penetrated in the Emu No. 1 Well show all the typical features of the Observatory Hill Beds, such as the cherty limestones, chert breccia and the high percentage of K-feldspars.

There can be little doubt, if any, that the section observed in the type section and the sequence encountered in Emu No. 1 Well belong to the same depositional event. Figure 4 shows a possible correlation between the type section and the well, a distance of about 26 miles (see Fig. 2). Although this correlation can only be tentative it agrees with the observed predominance of outcrops of arenaceous sediments to the north of the type section. The slight thinning towards the type section would be in keeping with the more peripheral position of this locality.

Regional Distribution and Age

Intermittent exposures of thinly bedded greywacke and arkoses occur to the north-east of Emu Field and they have been observed over a distance of some 40 miles. No work has been carried out along the eastern margin of the Officer Basin beyond that point and the area of the Everard 1:250,000 map sheet. Near

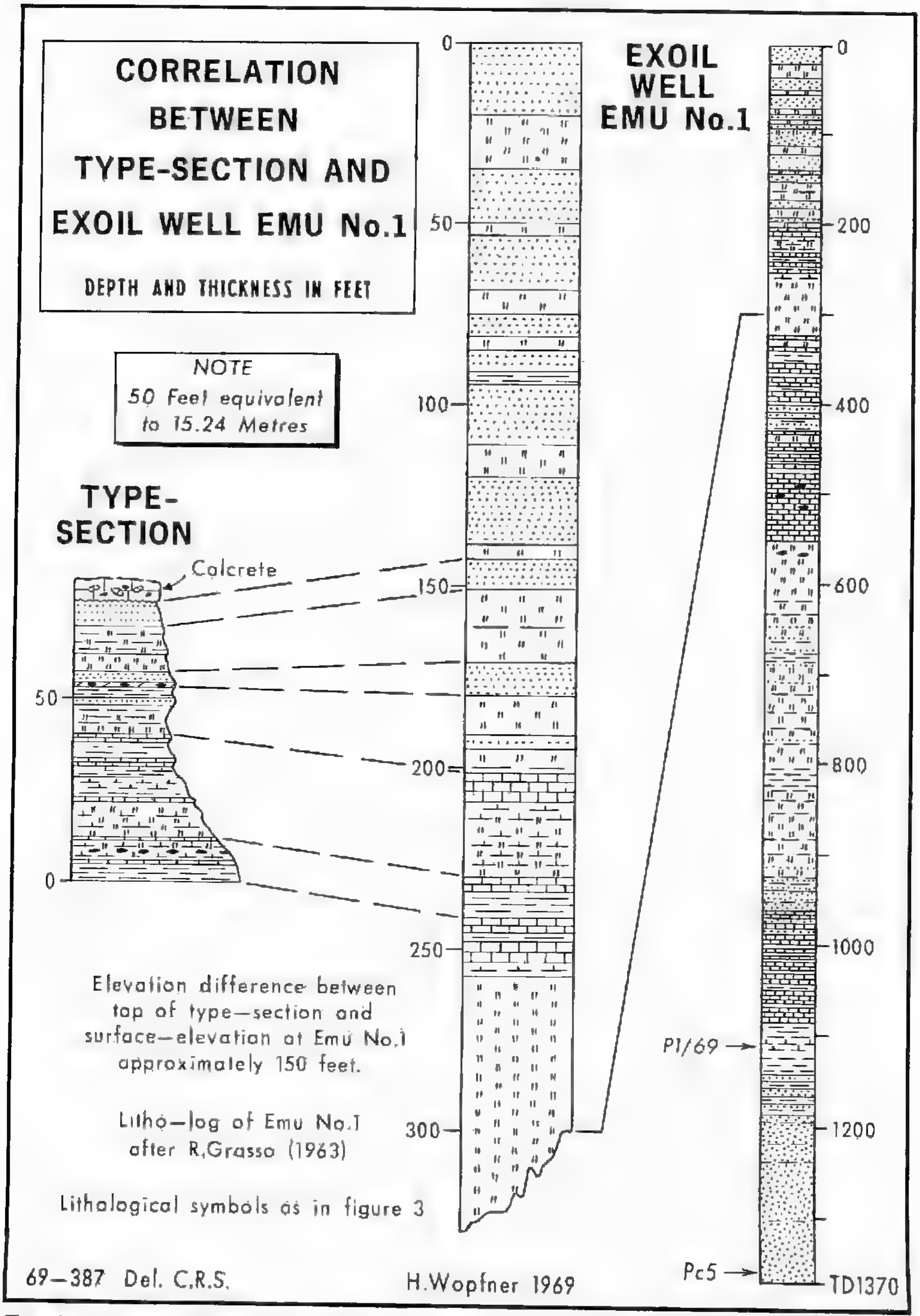

Fig. 4. Correlation between type section and sequence penetrated in the Exoil Well Emu No. 1. Top section of Emu Well has been enlarged (central column) for greater detail.

the eastern margin of that map area, south of Wallatinna water hole G. Krieg and R. Major mapped a sequence of siltstones with nodular chert concretions and thinly bedded to laminated greywacke. The sediments exposed at this locality show all the typical features observed in the type section of the Observatory Hill Beds and there is no doubt in the author's mind, who visited this section in 1968, that these are rock equivalents of the Observatory Hill Beds. Krieg (in press) correlates the Observatory Hill Beds at Wallatinna with a sequence at the north-eastern foot of the Mt. John Range, consisting of a basal conglomerate—"with components derived from an Adelaidean and granitic terrain—cherty siltstone characterised by nodules, lenses and irregular bands of chert and red, fine grained, cross-bedded greywacke-sandstone. The conglomerates are confined to the vicinity of Mt. John Range beyond which they grade laterally into finer clastics." These equivalents of the Observatory Hill beds overlie the Adelaidean sediments with marked unconformity and they are capped, apparently conformably, by the Mt. Chandler Sandstone which is generally regarded to be of early Ordovician age. On this evidence it would appear that the Observatory Hill Beds have to be placed somewhere within the Cambrian.

Red cherty siltstones, shale and greywacke-sandstones are exposed intermittently to the east of Serpentine Lake. As the lithology and mineral composition of these sediments are very similar to the greywacke in the type-area (see P299/68 in the Appendix) they are tentatively considered to represent Observatory Hill Beds.

The first attempt at correlating the Observatory Hill Beds with sediments outside the type area was made by Barnes (1956) who equated these sediments with a sequence of dark red sandstones, purple shale and siltstones and green sandstones encountered below Tertiary sediments in the Maralinga water bores. One of these bores penetrated 1,090 feet of these sediments and bottomed in crystalline basement to 1,724 feet. Barnes (op. cit.) suggested a late Precambrian to Cambrian age for the lower, red-bed sequence and a Palaeozoic to early Mesozoic age for the upper, generally green coloured succession. Ludbrook (1961) subsequently carried out palaeontological work on the bore samples. No fossils were found in these sediments and Ludbrook (op. cit.) suggested a late Precambrian (Marinoan) age for both the red-beds and the green coloured sediments, comparing them with the Tent Hill Formation of the Port Augusta-Woomera region.

Red-beds are of course a very common and widespread sediment type in South Australia. They are known from Precambrian stages in the Adelaide Geosyncline, they were developed extensively during the Cambrian and they are again common in Devonian sequences. The lithological characteristics of the Observatory Hill Beds compare most favourably with the middle to late Cambrian Lake Frome Group (Daily, 1956) of the Flinders Ranges.

The sedimentological features particularly of the lower two units of that group, the Moodlatana and Balcoracanna Formations, are almost identical. These formations are composed of green and red siltstones, arkoses, greywacke-sandstones, calcareous siltstones, and of dolomites and limestone, commonly with chert bands and breccia. The clastic sediments are characterised by a high feldspar content (20-40%) and they are richly micaceous and often biotitic. These two lower units are capped by a current-bedded arkose, the Pantapinna Sandstone of Dalgarno and Johnson (1965).

The sediment sequence and the lithological characteristics of both the Observatory Hill Beds and the Lake Frome Group suggest a depositional environment which required specific tectonic control not only of the basin area but also of the region which furnished the detrital material.

It is for this reasoning, combined with the evidence presented from the Mt. John Range, that a middle to late Cambrian age is suggested for the Observatory Hill Beds.

Environment

The Observatory Hill Beds are substantially the product of a shallow water environment in which they were laid down under generally oxidising conditions and under low to medium levels of energy. The uniformly high contents of detrital feldspars and micas, the generally ill sorted nature of the clastics and high proportion of clay size particles requires rapid burial of the sediments and a proximity of a metamorphic and igneous source area which underwent active and continuous erosion. In order to maintain such a situation over an extended period of time, downwarp of the basin must be compensated by uplift of the source area and *vice versa*. In other words, such an environment can only be maintained during periods of tectonic instability.

The first downwarp, which initiated the depositional period of the Observatory Hill Beds appears to have been rapid. In the north-eastern portion of the basin (Mt. John area) a gradient of sufficient magnitude was created, to facilitate transport of cobbles and pebbles into the basin while elsewhere medium grained, feldspathic sands were deposited. After this initial tectonic episode, sedimentation was largely controlled by oscillating periods of stability and reactivation of tectonic instability. This is demonstrated by a tendency to cyclic deposition, for instance the repetition of gradational shale-carbonate sequences observed in the type section (unit 8 → unit 9 → units 10 and 11). Each of these "cycles" may be interpreted as having resulted from fluctuations of the gradient between the source area and the depositional "base" within the basin. Intermittently the basin was filled to such a level that portions of the sediments became exposed above water level, dried out and formed mud cracks.

The texture of the carbonates is characteristic of chemically deposited limestones and dolomites. This, together with their thinly laminated nature and the coprecipitation of silica (chert) and the deposition of gypsum indicates a mildly evaporitic environment with above normal salinities. The high concentration of CO_3 may also have been responsible for the retention of the scapolites observed in some of the carbonate rocks.

A generally higher energy level, manifested by the predominance of arenaceous sediments, prevailed during deposition of the upper parts of the Observatory Hill Beds. The extremely thinly bedded greywacke and arkoses are difficult to interpret but they have certain affinities to deposits of the intra-tidal zone.

The mineral composition of the Observatory Hill Beds shows that the terrigenous material was derived from a source area largely composed of metamorphics of the granulite facies, with lesser contributions from both acid and basic igneous rocks. Along the southern and eastern margin of the Officer Basin the terrigenous material was most likely supplied off the Gawler Range Platform whilst the Musgrave Block may have contributed clastic components into the northern portion of the basin.

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APPENDIX

Petrographic Descriptions

The following petrographic descriptions of selected samples of Observatory Hill Beds are here presented as additional evidence for the characteristic lithology and mineral composition of this stratigraphic unit and also in support of the interpretations on depositional environment and provenance. The visual estimates of constituents have been summarized in table-form and are included in the main part of this paper.

The petrology was carried out by R. Davy (P287/68 to P299/68) and A. Kelly (P1/69) of the Mineralogy Section of the Australian Mineral Development Laboratories in Adelaide. The description of sample PC5 by W. B. Bryan was taken from the Well-completion report of Emu No. 1 (Grasso, 1963). The descriptions are grouped in 3 parts, namely (a) samples from the type section; (b) surface samples from the Emu region and Serpentine Lake and (c) core samples from the Exoil well Emu No. 1.

(a) Samples from the type section.

Sample No. P293/68: 7 feet above base.
Dolomitised Limestone with Chert nodules.

The hand specimen is a creamy grey, fine grained rock with red, rounded nodules of chert along apparent bedding planes. Weathering dissolves the matrix and leaves the cherty material standing proud on the surface.

Thin section: The rock was composed primarily of calcite and chert. Subsequently there has been secondary dolomitization in a patchy fashion and the development of large rounded segregations of chert containing veinlets of quartz. The segregations appear to be diffusion phenomena. The chert contains small spheroids of fibrous silica, occasional flakes of calcite and a host of minute inclusions virtually opaque because of their size. These appear to be isotropic, are reddish and probably some form of iron oxide. Dolomite has started to pentrate the chert. Grain size is that of silt for most of the rock, silt-clay grade in the chert layers.

Other minerals present in trace amounts include a deep green biotite and muscovite. The rock is a chemically precipitated limestone, partially dolomitised since deposition. For estimates of constituents see Table 2.

Sample No. P294/68: 10 feet above base.
Dolomitised Limestone with Chert.

Hand specimen: A massive fine grained rock, creamy or grey in colour which contains layers of fine grained, partly fibrous material. The latter layers are highly resistant to weathering and stand out on the weathered surface to a height of 3·5 mm.

Thin section: This is a dolomitised limestone similar to P293/68. It contains anhedral aggregates of calcite which have been partly replaced by dolomite, with the replacement at a higher level than in other slides. Within the rock there are vein-like segregations of dolomite and chert, and there are apparent former lithic fragments composed wholly of dolomite. These parallel the bedding and the variation. Quartz appears in the dolomitised calcite in anhedral detrital grains. Scapolite occurs with the dolomite in anhedral grains with fan-like extinction. Scapolite was confirmed by X-ray diffraction examination. Grain size is approximately silt size for most of the rock with the cherty layers more fine grained still. The sediment is a chemical limestone which has been secondarily dolomitised. Some silica present has been mobilised or has been introduced at a later stage and precipitated as chert. The dolomitisation may be almost contemporaneous. This is suggested by the presence of apparently lithic fragments of dolomite. For rock-composition see Table 2.

Sample No. P292/68: 14 feet above base.
Cherty Limestone.

Hand specimen: An irregularly laminated, multi-coloured sedimentary rock which shows much variation in grain size. Certain layers appear very fine grained, others are coarse with apparent grain diameters of 1-2 mm. The rock is stained pink over much of its volume, but

has yellow, maroon-black and brown layers. The banding appears to be a product of diffusion, not bedding.

Thin section: This is a chemically precipitated sediment composed of chert and calcite with a few grains of quartz and also fans of scapolite. The calcite is in irregular corroded masses of quite large grains and there are signs of dolomite as a rim to some of the calcite. Grains may be up to 1 mm. in diameter. Comparatively rare grains of quartz occur dispersed through the rock. Chert forms discrete layers and has also penetrated into the carbonate rich areas in the interstices between the grains.

The sediment was formed by chemical coprecipitation of calcite and chert, modified by later diffusion and corrosion. For estimates of constituents see Table 2.

Sample No. P287/68: 17 feet above base.

Cherty Limestone.

The hand specimen shows two types of sediment. The main portion is a grey, fine-grained rock containing greenish patches. The other is red and yellow in patches and appears to contain chert as a secondary material. Patches of the grey rock are contained within the red and yellow "filaments". The chert layer is more resistant to weathering.

Thin section: The rock is composed of an intimate mixture of calcite (70-80%) and quartz (10-35%) which have apparently coprecipitated as small anhedral grains (averaging 0·04 mm. but ranging up to 0·18 mm.). Part of the limestone has been replaced by a vein-like aggregate of opaline chert (10-20%) which contains grains of the limestone apparently broken off and incorporated into the chert, and part is replaced by dolomite (1-2%). The chert shows corrosive junctions with the limestone. The chert is stained light brown and also contains small grains of limestone. Small patches of chert also occur within the main limestone and appear to be lithic fragments derived from some earlier phase of silicification. Dolomite rims or replaces calcite grains. The only other minerals present are hydrated iron oxides and leucoxene. Some of the calcite has been recrystallised into larger grains in the area adjacent to the vein. Grain size for the calcite averages 0·05 mm.; for the chert lower still.

This is a chemical limestone with secondary deposition or segregation of chert.

Sample No. P288/68: 22 feet above base.

Arenaceous Limestone.

The hand specimen is a uniform, medium to fine grained rock containing white "spherulites". There are occasional reddish grains within the main mass of the rock. There are only traces of a bedding, lines visible may be related to proximity to the surface.

Thin section: A rock of silt or fine sand grade with occasional coarser fragments. Calcite and quartz are the two chief constituents and both occur as small irregular grains. Clay is also present between the grains and the minerals present in accessory amounts are dispersed through the rock. One coarse fragment of scapolite 3 mm. long was seen. There is at best only a very rough trace of bedding which is shown by a tendency to parallelism of some of the coarse fragments. The feldspar shows albite-type twins and is probably oligoclase albite (about An_{10}). Dolomite replaces and rims calcite grains in a few places.

Grain-size varies from 0·15 mm. for the quartz to, typically, 0·08 mm. for the calcite.

A special feature of this specimen are large grains (0·8-1·2 mm.) of red oligoclase albite with minute inclusions of hematite.

This sediment is probably largely of clastic origin. Some of the carbonate may have been chemically precipitated. There has been much erosion of metamorphic rocks followed by short transportation and reasonably quick burial. The rock has not been secondarily recrystallised. An interesting exotic is the large single crystal of scapolite. For estimates of constituents see Table 1.

Sample No. P289/68: 33 feet above base.

Arenaceous Limestone.

The hand specimen shows a massive, hard, fine grained, laminated sediment. The colour varies from light to dark grey and weathers brown. Bedding is rather variable and appears to be irregular owing to current action.

Thin section: This has been an arenaceous limestone and contains a mosaic of anhedral quartz and calcite, with subordinate clay. However the calcite has been attacked and partly replaced by dolomite which appears in some grains as a rim round the centre. The micaceous minerals and elongate quartz crystals show a rough parallelism indicative of bedding, the latter being emphasised by bands of differing proportions of minerals, especially by the differing proportions of clay. The opaque minerals are, for the most part, scattered through the rock (where they appear to be mica altered to iron ore, traces of mica remain in places) but also occur along bedding cracks or former solution channels. The primary mineral seems to have been hematite but it is now largely limonite. A few opaque grains show outlines consistent with e.g. brachiopod shell sections. No definite trace of fossils was found. The grain diameter averages 0·1 mm. The constituents are shown in Table 1.

Sample No. P290/68: 54 feet above base.

Banded chert-carbonate rock.

The hand specimen is a fine grained, irregularly banded (bedded) sediment. The layers are apparently of different composition and this has produced variegated bands, some of which are pink, greenish-grey, dark grey, and light grey. Manganese dioxide stains appear on the surface.

Thin section: The rock consists of calcite, dolomite, quartz, chert, feldspar, green biotite, muscovite and, in accessory amounts tourmaline and leucoxene. It is however impossible to give accurate proportions as the minerals are concentrated in different layers. In general calcite is the most abundant mineral, but in some layers it is in the process of being replaced by dolomite. In other layers chert is the most common mineral with calcite and dolomite subordinate. Quartz is present in the calcite-rich layers but in subordinate amounts; it is anhedral and detrital. The layers range in thickness from 0·4 mm. to over 1 cm. Other minerals are fairly evenly dispersed except that the chert contains no micaceous material or tourmaline. Dolomite is definitely secondary and is present (a) as a cement, (b) in small rhombs, and (c) rims on calcite. Its definite tendency to take crystal forms contrasts strongly with the calcite. Quartz grains are less common in the carbonate layers than in specimens P287/288/289. They are detrital in origin.

Certain of the chert layers have been cracked and the cracks have been infilled with calcite. The chert layers show a form of graded bedding with calcite at the apparent bottom. Grain size is typically 0·06 mm. or below.

The apparent bedding may reflect true bedding but it has almost certainly been modified by diffusion.

The thin sample represents a sedimentary sequence with alternations of chemically precipitated carbonate and silica.

Sample No. P29/168: 74 feet above base.

Feldspathic Greywacke.

Hand specimen. A dark chocolate brown rather variably bedded sandy rock. The rock shows variable bedding derived from mild turbulence and current bedding. Light coloured mica shows on the bedding surfaces.

Thin section: A visual estimate of the constituents is given in Table 2. The rock is composed of largely anhedral grains of quartz and feldspar, together with laths of muscovite and oxidised biotite. The interstices between the grains are filled with clay. This is subordinate, and much of the space between the grains has been filled by secondary overgrowth of silica or by apparent redistribution of silica. A few fragments are of rounded masses of chlorite, apparently representing former ferromagnesian minerals. Microcline remains fresh but untwinned K-feldspar and the K-feldspar microperthite are both sericitized. The K-feldspar microperthite is of the tubular vein perthite commonly associated with the granulite facies. Albite is rare and fresh and, in one case, euhedral. Other, more calcic plagioclase (?andesine) is severely altered.

The biotite is unusual in that it is almost opaque being now replaced by one of the hydrated iron oxides. As this specimen comes from the surface this may be a weathering feature. Mica is normally approximately parallel to the bedding.

Other minor minerals present include tourmaline (rounded), zircon (rounded) and probably primary iron oxides. The considerable void space means that the rock is probably highly porous. The grain size of the framework is typically $0{\cdot}3 \times 0{\cdot}15$ mm.

This is an arkosic sediment derived, in part at least, from the weathering and erosion of rocks of the granulite facies.

(b) Surface samples from the Emu region and from Serpentine Lake. (See Fig. 2 for sample location.)

Sample No. P295/68: 4 miles north of Observatory Hill, on south shore of large playa lake.

Arkose.

The hand specimen consists of a dull brown sandy porous rock, containing abundant sericite-muscovite on exposed surfaces. There are signs of incipient bedding only.

Thin section: (See Table 2 for estimate of constituents.) The rock is composed of anhedral to subrounded grains of quartz, feldspar, muscovite and aggregates of sericite grains set in a matrix of clay. There is little cementing material and there are abundant voids. The quartz commonly shows ironstained rims and in many grains shows overgrowths of secondary quartz. Any elongate crystals are arranged subparallel to the bedding; these are chiefly muscovite, the apatite, and some grains of quartz. Feldspar is mainly microcline but oligoclase-andesine in the ratio of 1:10 also appears; all feldspar is commonly partly sericitized. Clay appears as a cement and also as rounded grains or pellets apparently squashed during compaction. The average grain diameter is 0·12 mm.

The sample represents a detrital arkosic sediment which has largely been cemented by redistribution of silica. Some clay is also present but contributes little to the cementation.

Sample No. P296/68: 4 miles south of Emu field on Maralinga track.
Arkose.

The hand specimen is a buff coloured "sandstone" which shows traces of layering. "Sericite" shows on the broken bedding surface. This rock is probably fairly rich in iron as it weathers to a deep red brown surface layer.

Thin section: (A visual estimate of the constituents is given in Table 2.) The rock is composed of anhedral grains of quartz, microcline, perthitic K-feldspar, ?andesine, muscovite, sericite grains and opaque material (mainly limonite). There is little cement; what there is, is clay. Most cementation has been caused by overgrowth of silica on the former quartz grains, which have locked the grains together in an anhedral mosaic. Much pore space remains. Some of the feldspar shows the vein perthite texture of feldspar from granulites. Microcline is fresh. Other feldspar is more or less altered to sericite; however, the original properties are still partly visible. K-feldspar is more abundant than plagioclase, by about 4:1. The opaques appear to be "limonite". The average grain diameter is about 0·2 mm.

This is a clastic rock, derived, in part at least, from the erosion of acid metamorphosed rocks. Cementation is primarily effected by the development of overgrowth of quartz.

Sample No. P297/68: 2 miles south of Emu field, on Maralinga track.
Feldspathic Greywacke.

The hand specimen is a thinly bedded, pinkish-cream sandstone. The banding appears to be formed by the selective concentration of darker/lighter minerals. Bedding is fine, of the order of 1 or 2 mm., and very uniform.

Thin section: (A visual estimate of the constituents is given in Table 2.) This rock differs from those previously described, by virtue of the larger concentration of clay and chlorite. The framework, consisting of quartz and feldspar, tends to have more elongate grains, which tend to be discrete, and these grains tend to have their axes parallel to the bedding. The quartz, as before, commonly shows overgrowths of secondary silica. There are a few grains of former quartzite; feldspar is both microcline and plagioclase, with altered untwinned, or microperthitic K-feldspar. K-feldspar exceeds plagioclase by over 10:1. Sericite is the normal alteration product of both feldspars and even fresh feldspars appear mildly kaolinised. Grain size tends to be about 0·3 × 0·15 mm. in the largest grains.

This sedimentary rock is of clastic origin. Grains in general are more rounded than angular, though they may be elongate. The rounded habit of the grains is produced more by secondary silicification than by transport.

Sample No. P298/68: south-east of Emu Field hut.
Feldspathic Greywacke.

The hand specimen is a massive, cream coloured, fine grained "sandstone" which shows muscovite on the crude bedding surfaces visible.

Thin section. The framework of the rock consists of quartz, feldspar and mica with accessory minerals, embedded in a clay-matrix. A quantitative estimate of the mineral composition is given in Table 2. The average grain size is 0·3 mm. × 0·15 mm. but laths of muscovite extend to 0·5 mm. This is a bedded fine greywacke with arkosic tendencies, which has been formed by the weathering of acid rocks probably, at least partly, of the granulite facies of metamorphism, as one or two grains of feldspar have the characteristic vein (tubular) perthite texture. Sedimentation and burial have been rapid to preserve the abundant anhedral fresh (except for light kaolinisation) feldspars. Microcline exceeds plagioclase by approximately 10:1. Plagioclase appears to be oligoclase-andesine. The quartz is also in generally elongate anhedral grains and commonly shows secondary overgrowth. The matrix is composed largely of clay with fine grained quartz. Minor amounts of anhedral leucoxene, and irregular tourmaline, rutile and clinozoisite also occur. Bedding is shown by the approximate parallelism of elongate grains.

This rock is very similar to P299/68 and its origin appears to be the same. Compared with that rock, this has slightly more clay and shows more signs of oxidation. Compared with P297/68 there is much less clay.

Sample No. P299/68: 5 miles east of Serpentine Lake, near Western Australian border.
Feldspathic Greywacke.

Hand specimen: A medium-fine grained, creamy, "sandstone" which shows flakes of muscovite on the bedding surfaces. Traces only of bedding are seen and the rock breaks very roughly on these surfaces. This would probably qualify as a freestone on the evidence of the hand specimen.

Thin section: This sediment is intermediate in properties between P287/68 and P295/68 and P296/68. This is rich in quartz, feldspar and sericite/clay. The last named may occur as pellet-like grains as well as in the matrix. As before microcline is the most common feldspar, with untwinned (?)cryptoperthite K-feldspar second, and plagioclase (uncertain) last. K-feldspar exceeds plagioclase by 10:1. The feldspar and quartz occur as anhedral grains. Some feldspar is highly sericitised (? a calcic plagioclase), most is fairly fresh, microcline in

particular being unaltered. The average grain size is 0·15 mm. There is no sign of sorting. An estimate of constituents is given in Table 2. The sediment is related to an arkose which has been buried quickly and formed from material which has not been transported very far. Probably derived from acid igneous or high grade metamorphic rocks.

Comparison of arenaceous rocks P291/68, P295/68, P296/68, P297/68, P298/68 and P299/68

Four of these rocks are feldspathic greywackes, the other two (P295/68, P296/68) are arkoses. The distinguishing criterion for this is the proportion of matrix clay or clay/chlorite. The framework is of detrital quartz, anhedral but commonly with secondary overgrowths, and feldspar. K-feldspar exceeds plagioclase by over 10:1 except in P296/68 where andesine is present in some abundance. The plagioclase is not always clearly recognisable, but there are two sorts albite and andesine (P291/68). The plagioclase does not give a figure in most slides, and identification has been by refractive indices and extinction angles were possible. Where the plagioclase has been highly altered even the above determination was not possible. K-feldspar occurs in three forms: microperthitic and very like K-feldspar from rocks of the granulite facies (P291/68), microcline (P298/68), and untwinned K-feldspar. It is suggested that the last may be an intermediary between the two former. The microcline has been derived from plutonic or metamorphic rocks, probably the latter. Some of the K-feldspar in P291/68 and P298/68 shows that vein perthite texture normally characteristic of rocks of the granulite facies.

No original ferromagnesian minerals remain, but there are rounded pellets of a mass of chlorite, or sericite, which possibly were once more formal ferromagnesian minerals. These occur in P291/68, P296/68 and P299/68. There is little biotite, and this is being oxidised to "limonite" presumably by weathering at the surface.

The groundmass is either clay or a mixture of clay with chlorite (P297/68). Both are pale coloured, brown for the clay, brownish green for the chlorite. Other clay material is provided by a few squashed pebbles and pellets which appear to be transported, and are probably rounded remnants of earlier shale. They are distinct from the suspected ferromagnesian material and occur in P295/68 and P299/68.

The two arkoses (P295/68, P296/68) are exceptional in their low content of matrix material. Texturally they are very similar but P295/68 is more fine grained than the other. In both the grains are well sorted though P296/68 has a better sorting than P295/68. Many of the grains of P295/68 are now irregular-rounded where once they seem to have been angular, modified because of the secondary overgrowth of silica. Overgrowths are still prominent in P296/68 but by contrast, are not as common. A difference between the two is the presence of subparallel and quite large laths of muscovite in P295/68.

It appears that all these six samples are lithologically related with variations in quantity of matrix, grain size and type of feldspar. Sedimentation has been rapid and the clastic material used has been derived from an area of granulite facies metamorphic rocks with probably both acid and basic components contributing.

(c) Core samples from Exoil well Emu No. 1.

Sample No. P1/69: core No. 4, 1,105 feet.

Greywacke-siltstone (?turbidite) with a gypsum vein.

The hand specimen is a reddish-brown, thick-bedded finely but irregularly laminated muddy sediment. A single bedded vein, 1 cm. thick, of palisade structure and containing a thin raft of the host-rock, occurs at one end of the core-specimen.

Thin section: Microscopically the texture indicates much poorly sorted material. The bulk of the rock is of shaly character but minor, distorted and frequently discontinuous laminae of submillimetre thickness carry high proportions of grains up to fine sandstone sizes (to 1 mm). In some laminae these grains are fairly well sorted and have a sandstone texture whereas in others the texture is that of a greywacke. Other coarse grains are incongruously distributed throughout the shaly parts.

Minerals forming the rock are major quartz, calcite and microcline, minor albite, biotite, muscovite, chlorite, dusty iron oxides (?hematite), ?sericite and traces of tourmaline. Heavy staining by micron-sized iron oxides and the highly variable, fine grain size makes visual estimation of the mineral proportions unreliable, but it is evident that the three major minerals form at least 80% of the whole and occur in roughly equal proportions. Hematite forms an estimated 2-3% of the rock.

Some of the coarser quartz, calcite and microcline grains are well rounded and of detrital origin. However, the bulk of the calcite is fine-grained and recrystallised and probably originally chemically precipitated. The structure of the rock suggests a turbidite origin for the bed.

The vein is of gypsum; the identity of the mineral was confirmed by X-ray diffraction.

The origin of the iron oxides and the gypsum may be connected; accessory hematite grains 5 micron across may be pseudomorphous after fine-grained sedimentary pyrite. The mineral (?pyrite) forms only 1% of the bed.

Sample No. Pc5: core No. 5, 1,357 feet.
Feldspathic sandstone.

The core sample is a medium grained, porous sandstone without apparent bedding.

Thin section: The sample is composed of well rounded to moderately well rounded sub-spherical grains of quartz, microcline, and lithic fragments, in order of decreasing abundance. Accessory minerals include tourmaline pleochroic in green and blue as occasional rounded grains; rutile as needles in quartz; and apatite, as relatively stout prisms enclosed in quartz. The lithic fragments appear to be composed of siliceous or ferruginous shale.

The rock is definitely transitional to an arkose, and cannot be precisely classified without exact modal data. The name "feldspathic sandstone" seems most appropriate as there is little or no argillaceous material.

The average grain size is about 0·3-0·5 mm., and porosity appears high. Grains are weakly cemented by a fine-grained birefringent material which also lines the pore spaces. This is too fine to be accurately identified optically. It is definitely not calcite as it does not react to acid. Birefringence is too high for most phosphates, although the moderate relief is characteristic of such minerals. Dolomite would be expected to show some evidence of rhombohedral crystal form. A phosphate such as francolite or dahlite remains the most likely possibility.

EXPLANATION OF PLATES

Plate 1

(a) View of type section of Observatory Hill Beds, 4 miles west of Observatory Hill. The sediments are of flat lying and the benches are formed by carbonate beds. Man in middle-ground is standing on unit 5. (Photo: H. Wopfner.)

(b) Upper part of Observatory Hill Beds, showing thinly bedded nature of sediments. Mr. J. McG. Hall is standing just above top of unit 9. (Photo: H. Wopfner.)

Plate 2

(a) Laminated dolomite, chert and limestone (unit 17) in type section. (Photo: H. Wopfner.)

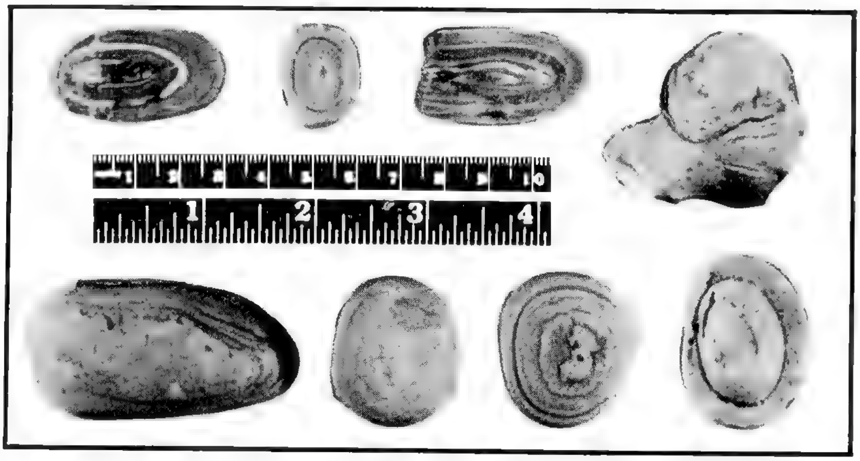
(b) Concentric chert-concretions from type section of Observatory Hill Beds.

(c) Specimens on left and lower right of picture show bottom-faces of calcareous siltstones with infillings of mudcracks from units 6 and 2 respectively. Sample in top right-hand corner shows chert-blebs (light colour) on top of bedding plane of fine-grained sandstone.

(a)

(b)

(a)



(b)

(c)

BALANCE SHEETS:
GENERAL ACCOUNT AND RESEARCH FUND

Summary

THE ROYAL SOCIETY OF SOUTH AUSTRALIA INCORPORATED

Endowment and Scientific Research Fund

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 30th JUNE, 1969

RECEIPTS

	$	$
Opening Balance 1st July, 1968		587.38
Add Receipts		
Interest and Dividends Received	1,328.69	
Bank Interest	31.44	
Softwood Holdings Shares (sale of 300)	1,114.80	
		2,474.93
		$3,062.31

PAYMENTS

	$	$
Deduct Payments		
Purchase of Investments—		
17 Softwood Holdings Ords.	30.63	
280 Australian Consolidated Industries Ords.	615.68	
175 Lensworth Finance Ords.	131.25	
100 Herald & Weekly Times Ords.	447.76	
		1,225.32
Research Grants—		
C. R. Twidale	100.00	
I. M. Thomas & S. A. Shepherd	250.00	
D. Hayman	150.00	
		500.00
		1,725.32
Closing Balance 30th June, 1969		1,336.99
		$3,062.31

SCHEDULE OF INVESTMENTS AT 30th JUNE, 1969 (at cost)

	$	$
Fixed Deposits		
Lensworth Finance—8%	4,000.00	
G.M.A.C.—7½%	2,000.00	
F.C.A.—7¾%	2,000.00	
E.I.L.—8%	900.00	
F.N.C.B. Waltons—7¾%	2,000.00	
		10,900.00
Equity Stock		
Woolworths—900	1,290.00	
Australian Consolidated Industries—680	1,742.68	
Adelaide Cement—1,000	1,275.00	
Colonial Sugar Refineries—400	1,283.00	
Herald and Weekly Times—550	1,814.76	
Tooths—250	1,330.00	
Imperial Chemical Industries—500	1,063.00	
Lensworth—875	1,190.17	
Softwood Holdings—Prefs.—400	800.00	
		11,788.61
Inscribed Stock		300.00
Cash at Bank		1,336.99
		$24,325.60
Note: Market Value of Equity Stock 30th June, 1969		$14,370.00

Auditors' Report.

We report that we have examined the Books and Accounts of THE ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED) for the year ended 30th June, 1969, and have obtained all the information and explanations we have required.

In our opinion, the attached Statements of Receipts and Payments for the General, Library and Endowment Fund are properly drawn up to record the cash transactions of the Society for the year ended 30th June, 1969, according to the best of our information and the explanations given to us and as shown by the Books of the Society submitted. We have also verified the Schedule of Investments at 30th June, 1969.

Adelaide, South Australia,
4th September, 1969.

MILNE, STEVENS, SEARCY & CO.,
Chartered Accountants.

REPORT ON ACTIVITIES OF THE COUNCIL, 1968-69

Summary

REPORT ON ACTIVITIES OF THE COUNCIL, 1968-69

In 1969 the Society was honoured to receive the patronage of His Excellency the Governor of South Australia, Major-General Sir James Harrison.

It is a pleasure to report that during the past year there has been a marked increase in membership, increased attendance at Ordinary Meetings of the Society and an excellent response to new activities.

Twenty-four new Fellows were elected during the past year, and one Fellow resigned. In April, 1969, Honorary Fellowship was conferred upon Professor A. R. Alderman. The total membership of the Society now stands at 280.

The Council notes with pleasure that many members moving interstate or overseas are retaining their membership; at the present time 61 members reside outside of South Australia.

Seven ordinary meetings of the Society were held and attendances varied from 26 to 60 with an average of 39, compared with an average of 32 in the preceding year. Seven addresses were delivered at these meetings and six Exhibits were presented.

The twelve papers read at these meetings were concerned with the following disciplines: Botany 4; Geomorphology 2; Climatology 2; Palaeontology 1; Soil Science 1; Zoology 1.

At the instigation of the President, the Council at the beginning of the year formed a "Promotions Committee" which considered various aspects of the Society's activities and recommended various innovations. Amongst the recommendations was the organisation of a Conversazione, which was eventually held at the Park Royal Motor Inn in March, 1969. Approximately 30 exhibits of the varied scientific research activities of members were displayed and 150 members and their guests attended the function.

In August, 1969, the Council organised a Public Lecture held at the State Library Lecture Theatre. Professor R. Stebbins of the University of California delivered an address entitled "The University of California Expedition to the Galapagos Islands". This function attracted an audience of 110.

Nine meetings of the Council were held during the year.

In 1969 three awards were made from the Scientific Research and Endowment Fund to assist scientific research being undertaken by members of the Society:

Mr. F. S. Parker of Daru, Territory of Papua and New Guinea, was granted $250 towards costs involved in the collection of amphibians and reptiles.

Dr. D. L. Hayman and Mr. R. Hope of the Department of Genetics, University of Adelaide, received $150 to undertake a field study of serum proteins in the opossum, *Trichosurus vulpecula*.

Mr. R. C. Beck of Mil-Lel, South Australia, received $50 to defray travel expenses involved in a study of factors affecting the distribution of the frog, *Crinia laevis*, in South Australia.

The Library continued to operate efficiently and profitably. Five new exchanges were successfully negotiated, 195 volumes were bound, and a total of 350 volumes borrowed from the Library, mostly on interlibrary loan.

The Council has been investigating the possibility of reprinting some of the early volumes of the Transactions.

Volume 92 of the Transactions of the Society was published in December, 1968, together with an index to volumes 45-91. The volume contained 10 papers and comprised a total of 132 pages. The Society is greatly indebted to Dr. N. H. Ludbrook who undertook the compilation of the index.

The Council has been concerned at the steadily increasing costs involved in publishing the Transactions, and a deputation from the Council waited on the Hon. the Minister of Education and submitted a case for an increase in the government subsidy to the Society for the next financial year. The Council also feels it necessary at this stage to consider an increase in the annual subscription of Fellows.

OFFICERS FOR 1968-69

Summary

ROYAL SOCIETY OF SOUTH AUSTRALIA

INCORPORATED

Patron:

HIS EXCELLENCY MAJOR-GENERAL SIR JAMES W. HARRISON, K.C.M.G., C.B., C.B.E.

OFFICERS FOR 1968-69

President:

F. J. MITCHELL

Vice-Presidents:

K. R. MILES, D.Sc., F.G.S.

C. B. WELLS, M.Agr.Sc.

Secretary:

M. J. TYLER

Treasurer:

S. A. SHEPHERD, B.A., LL.B.

Editor:

J. K. TAYLOR, B.A., M.Sc., B.Sc.Agr.

Assistant Editor:

I. M. THOMAS, M.Sc., M.I.Biol.

Librarian:

N. H. LUDBROOK, M.A., Ph.D., D.I.C., F.G.S.

Programme Secretary:

D. E. SYMON, B.Agr.Sc.

Members of Council:

J. T. HUTTON, B.Sc., A.S.A.S.M.

K. E. LEE, D.Sc.

H. E. WOPFNER, Ph.D.

C. R. TWIDALE, M.Sc., Ph.D.

R. H. KUCHEL, B.Sc.

G. F. GROSS, M.Sc.

Auditors:

Messrs. MILNE, STEVENS, SEARCY & CO.

LIST OF FELLOWS

Summary

ROYAL SOCIETY OF SOUTH AUSTRALIA

LIST OF FELLOWS

Those marked with an asterisk (*) have contributed papers published in the Society's Transactions. Those marked with a dagger (†) are Life Members.

Any change in address or other changes should be notified to the Secretary.

Note: The publications of the Society are not sent to those members whose subscriptions are in arrears.

HONORARY FELLOWS

Date of Election	Date of Honorary Election	
1927	1969	*Alderman, Prof. A. R., Ph.D., D.Sc., F.G.S., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A. 5000. Council, 1937-42, 1954-57; Vice-President, 1962-63, 1964-65; President, 1963-64; Verco Medal, 1966.
1895	1949	*Cleland, Prof. Sir J. B., M.D., Dashwood Road, Beaumont, S.A. 5066. Verco Medal, 1933; Council, 1921-26, 1932-37; President, 1927-28, 1940-41; Vice-President, 1926-27, 1941-42.
1913	1955	*Osborn, Prof. T. G. B., D.Sc., 34 Invergowrie Avenue, Highgate, S.A. 5063. Council, 1915-20, 1922-24; Vice-President, 1924-25, 1926-27; President, 1925-26.
1925	1964	*Prescott, Prof. J. A., C.B.E., D.Sc., F.R.A.C.I., F.R.S., F.A.A., 82 Cross Road, Myrtle Bank, S.A. 5064. Verco Medal, 1938; Council, 1927-30, 1935-39, 1962-68; Vice-President, 1930-32; President, 1932-33; Editor, 1955-62.
1923	1965	*Tindale, N. B., D.Sc., South Australian Museum, North Terrace, Adelaide, S.A. 5000. Verco Medal, 1956; Secretary, 1935-36; Council, 1946-47; Vice-President, 1947-48, 1949-50; President, 1948-49; Librarian, 1952-66.

FELLOWS

Date of Election	
1946	*Abbie, Prof. A. A., M.D., D.Sc., Ph.D., Department of Anatomy, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1961	Abele, C., B.Sc., Ph.D., 4/123 Lennyoon Street, Elwood, Victoria 3184.
1968	Adam, J. R., B.E., A.M. Aust. I.M.M., Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000.
1959	Aitken, P. F., B.Sc., South Australian Museum, North Terrace, Adelaide, S.A. 5000.
1966	Allchurch, P. D., B.Sc., c/- Australian Selection Pty. Ltd., P.O. Box 50, Kalgoorlie, W.A. 6430.
1969	Amtsberg, H. E. O., 24 Kanbara Street, Flinders Park, S.A. 5025.
1961	Anders, D. J., B.Sc., B.Ed., M.A.C.E., 1 Seaforth Avenue, Hazelwood Park, S.A. 5066.
1951	*Anderson, Mrs. S. H., M.Sc., 138 Stephen Terrace, Gilberton, S.A. 5081.
1935	*Andrewartha, Prof. H. G., M.Agr.Sc., D.Sc., F.A.A., Department of Zoology, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1935	*Andrewartha, Mrs. H. G., B.Agr.Sc., M.Sc., 29 Claremont Avenue, Netherby, S.A. 5062.
1929	*Angel, F. M., 293 Fullarton Road, Parkside, S.A. 5063.
1939	*Angel, Miss L. M., M.Sc., Department of Zoology, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1968	Angove, P. C., R.D.A., M.A.I.A.S., Department of Agriculture, Gawler Place, Adelaide, S.A. 5000.
1960	Archbold, R. T., B.A., A.L.A.A., 26 Waller Crescent, Campbell, A.C.T. 2601.
1966	Ashraf, C. M., M.Sc., West Pakistan (address unknown).
1965	Aslin, F. W., 29 Elizabeth Street, Mt. Gambier, S.A. 5209.
1962	Bacot, P. H., 7 Findon Street, Hawthorn, Victoria 3122.

Date of Election

1963 BAILEY, Mrs. M. A., B.Sc. (Hons.), Ph.D., Department of Botany, University of British Columbia, Vancouver 8, British Columbia, Canada.

1963 BAILEY, A., B.Sc. (Hons.), Ph.D., Department of Botany, University of British Columbia, Vancouver 8, British Columbia, Canada.

1963 BALDOCK, R. N., B.Sc., 62 Robsart Street, Parkside, S.A. 5063.

1964 BARKER, S., Ph.D., Department of Zoology, University of Adelaide, North Terrace, Adelaide, S.A. 5000.

1969 BARKER, Miss S., M.Sc., Department of Geography, University of Adelaide, North Terrace, Adelaide, S.A. 5000.

1965 BARLOW, B. A., B.Sc., Ph.D., School of Biological Sciences, Flinders University, Sturt Road, Bedford Park, S.A. 5042.

1948 BECK, R. G., B.Agr.Sc., R.D.A., Lynwood Park, Mil-Lel, via Mount Gambier, S.A. 5290.

1969 BEGG, M. W., M.B., B.S., M.R.A.C.P., 20 Jasper Street, Millswood, S.A. 5034.

1932 BEGG, P. R., D.D.Sc., R.D.A., Shell House, 170 North Terrace, Adelaide, S.A. 5000.

1968 BEHRENS, D. von, South Australian Museum, North Terrace, Adelaide, S.A., 5000.

1928 BEST, R. J., D.Sc., F.R.A.C.I., F.I. Biol., M.A.I.A.S., P.O. Box 10, Moana Beach, S.A. 5169.

1934 †BLACK, E. C., B.A., M.B., B.S., 483 Magill Road, Tranmere, S.A. 5073.

1962 BLESING, Mrs. N. M., 50 Angus Road, Westbourne Park, S.A. 5041.

1968 BLISSETT, A. H., M.Sc., A.M. Aust. I.M.M., F.G.S., Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000.

1968 BOEHMER, S., B.A. (Mus.), Dipl.S.T., 10 Charles Street, Norwood, S.A. 5067.

1950 BONNIN, N. J., M.B., B.S., F.R.C.S. (Eng.), F.R.A.C.S., 19 Marlborough Street College Park, S.A. 5069.

1945 †*BONYTHON, C. W., B.Sc., F.R.A.C.I., Romalo House, Romalo Avenue, Magill, S.A. 5072.

1945 *BOOMSMA, C. D., M.Sc., B.Sc.For., 6 Celtic Avenue, Clovelly Park, S.A. 5042.

1962 BOYES, Mrs. A. J., Mus.Bac., A.U.A., "Mirrabooka", 69 Wilpena Street, Eden Hills, S.A. 5050.

1963 BROCK, B. J., B.Sc., 62 Mills Street, Clarence Park, S.A. 5034.

1957 *BROOKES, Miss H. M., Department of Entomology, Waite Institute, Private Bag No. 1, Glen Osmond, S.A. 5064.

1962 BROWN, R. C., B.Sc., Geology Department, University of Western Australia, Nedlands, W.A. 6009.

1961 *BROWNELL, P. F., Ph.D., University College of Townsville, Pimlico, Townsville, Queensland 4810.

1957 †BUICK, W. G., B.A., Library, University of Papua and New Guinea, Box 1432, Boroko, T.P.N.G.

1944 *BURBIDGE, Miss N. T., D.Sc., C.S.I.R.O., Division of Plant Industry, P.O. Box 109, Canberra, A.C.T. 2601.

1967 CALLEN, R. A., B.Sc. (Hons.), Department of Mines, Box 38, Rundle Street P.O., Adelaide 5000.

1966 CALLOW, K. J., B.Sc., c/- Delhi Australian Petroleum Ltd., 32 Grenfell Street, Adelaide, S.A. 5000.

1960 CANDLER, C., 8 First Avenue, Glenelg, S.A. 5045.

1968 CARRICK, J., B.Sc., State Herbarium, Botanic Garden, North Terrace, Adelaide, S.A. 5000.

1959 *CARRODUS, B. B., R.D.Oen., Department of Geography, University of Melbourne, Parkville, Victoria 3052.

1953 CARTER, A. N., M.Sc., Ph.D., 8 Scot Street, Maroubra Bay, N.S.W. 2035.

1963 CARTER, F. D., B.Ag.Sc., Waite Institute, Private Bag No. 1, P.O., Glen Osmond, S.A. 5064.

1957 *CHIPPENDALE, G. M., B.Sc., Raoul Place, Lyons, A.C.T. 2606.

1955 CLOTHIER, E. A., B.E., c/- Conzinc Rio Tinto (Aust.), 95 Collins Street, Melbourne, Victoria 3000.

1949 COLLIVER, F. S., Geology Department, University of Queensland, St. Lucia, Brisbane, Queensland 4067.

1962 CORBETT, D. W. P., Ph.D., F.G.S., 41 Hawthorndene Drive, Glenalta, S.A. 5052.

1969 CRAWFORD, A. L., 5 Downer Street, Plympton Park, S.A. 5038.

1956 *CRAWFORD, A. R., B.Sc., Department of Geophysics and Geochemistry, The Australian National University, Box 4, G.P.O., Canberra, A.C.T. 2600.

Date of Election

1963 CROWCROFT, W. P., M.Sc., D.Phil., Chicago Zoological Park, Brookfield, Illinois, 60513, U.S.A.
1956 DAILY, B., Ph.D., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A. 5000. Programme Secretary, 1957-59; Council, 1960-64; Vice-President, 1964-65, 1966-67; President, 1965-66.
1962 *DALGARNO, C. R., M.Sc., Thirkell Street, Beaumont, S.A. 5066.
1969 DAVISON, E. M., B.Sc., Ph.D., Botanic Garden, North Terrace, Adelaide, S.A. 5001.
1968 DAVY, R., B.Sc. (Hons.), A.M.I.M.M., F.G.S., Australian Mineral Development Laboratories, Conyngham Street, Frewville, S.A. 5063.
1964 DEARLOVE, T. R., M.B., B.S., 25 Harvey Avenue, North Glenelg, S.A. 5045.
1930 DIX, E. V., P.O. Box 12, Aldgate, S.A. 5154.
1957 DOULL, K. M., M.Ag.Sc., Waite Institute, Private Bag No. 1, P.O., Glen Osmond, S.A. 5064.
1964 DRAGOVICH, Mrs. D. J., B.A. (Hons.), c/- 40 Ingerson Street, West Beach, S.A. 5024.
1963 DRAYTON, R. D., B.Sc. (Hons.), 17 Eton Street, Colonel Light Gardens, S.A. 5041.
1959 DUNLOP, P. R. C., B.Sc., 13 Walton Avenue, Clearview, S.A. 5085.
1931 DWYER, J. M., M.B., B.S., 157 East Terrace, Adelaide, S.A. 5000.
1968 DYKE, N. W., M.I.I.C.A., 57 Balcombe Avenue, Seaton, S.A. 5023.
1933 *EARDLEY, Miss C. M., M.Sc., F.L.S., Department of Botany, University of Adelaide, North Terrace, Adelaide, S.A. 5000. Council, 1943-46.
1963 EDDY, Mrs. N. C., 110 Mitchell Street, Darwin, N.T. 5790.
1945 *EDMONDS, S. J., B.A., Ph.D., Department of Zoology, University of Adelaide, North Terrace, Adelaide, S.A. 5000. Council, 1954-55; Programme Secretary, 1955-56; Secretary, 1956-57; Vice-President, 1963-64, 1965-66; President, 1964-65.
1962 *EDWARDS, R., South Australian Museum, North Terrace, Adelaide, S.A. 5000.
1956 *EICHLER, Hj., Dr.rer.nat., State Herbarium, Botanic Garden, North Terrace, Adelaide, S.A. 5000.
1968 ERNST, L. K., 50 Airdrie Avenue, Findon, S.A. 5023.
1968 FAIRBURN, W., B.Sc. (Hons.), A.M. Aust. I.M.M., c/- Carpentaria Exploration & Pty. Ltd., 567 Main South Road, Everard Park, S.A. 5035.
1969 *FANDER, H. W., M.Sc., 3 Yongala Street, Tranmere, S.A. 5073.
1965 FENNER, T. L., B.Ag.Sc., Entomology Section, Department of Agriculture and Forestry, Konedobu, Territory Papua-New Guinea.
1959 *FIELDER, D. R., B.Sc., Ph.D., Department of Zoology, University College of Townsville, Pimlico, Townsville, Queensland 4810.
1963 *FIRMAN, J. B., B.Sc. (Hons.), 11 Wilkins Street, East Glenelg, S.A. 5045.
1951 FISHER, R. H., 21 Seaview Road, Lynton, S.A. 5062.
1966 FLEMING, H. D., B.E., F.S.A.S.M., M.I.E. Aust., 104 Marian Road, Payneham S.A. 5070.
1958 *FORBES, B. G., Ph.D., Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000.
1959 FORDE, N., Dip.For., Western Teachers College, 70 South Road, Torrensville, S.A. 5031.
1962 FOSTER, R. J., B.E., 2 Rendell Court, Hughesdale, S.E. 12, Victoria 3166.
1964 FREEMAN, R. N., M.Sc., Edificis Ecuatoriana-Suiza de Seguros, FCO de P. Ycaza 203, 7° Piso, Box 6400, Guayaquil, Ecuador.
1962 *FREYTAG, I. B., B.Sc., 2 Selway Street, Oaklands Park, S.A. 5046.
1954 GIBSON, A. A., A.W.A.S.M., 2 Boyle Street, Oaklands Park, S.A. 5046.
1953 *GLAESSNER, Prof. M. F., D.Sc., F.A.A., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1964 GLOVER, C. J. M., B.Sc., South Australian Museum, North Terrace, Adelaide, S.A. 5000.
1935 †GOLDSACK, H., Coromandel Valley, S.A. 5051.
1969 GOODWINS, I. R., Department of Genetics, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1964 GORDON, Miss E. M., Lot 32, Titree Road, Stirling, S.A. 5152.
1963 GRAETZ, R. D., B.Sc. (Hons.), Environmental Biology Group, Research School of Biological Sciences, Australian National University, Canberra City, A.C.T. 2601.
1963 GRASSO, R., M.Sc., 8 Bransby Avenue, Plympton, S.A. 5038.
1959 GREEN, Miss L. M. A., B.A., M.Sc., Ph.D., Department of Anatomy and Histology, University of Adelaide, North Terrace, Adelaide, S.A. 5000.

Date of Election

1969 GREENSLADE, P. J. M., M.A., Ph.D., C.S.I.R.O., Division of Soils, Private Bag No. 1, Glen Osmond, S.A. 5064.
1969 GREENSLADE, Mrs. P. J. M., M.A., 8 Fourth Road, Belair, S.A. 5052.
1961 GREEN, W. J., B.Sc., Beaver Exploration Australian N.L., Bank of Adelaide Building, 275 George Street, Sydney, N.S.W. 2000.
1962 †GREGORY, G. C., M.B., B.S., Leigh Creek, S.A. 5731.
1948 GROSS, G. F., M.Sc., South Australian Museum, North Terrace, Adelaide, S.A. 5000. Secretary, 1950-53; Council, 1968-.
1944 GUPPY, D. J., B.Sc., 22 Chermside Street, Deakin, A.C.T. 2600.
1962 HAMILTON-SMITH, E., A.U.A., 17 Helwig Avenue, Montmorency, Victoria 3094.
1962 HARDING, J. H., B.Sc., 92 East Avenue, Clarence Park, S.A. 5034.
1946 *HARDY, Mrs. J. E., M.Sc., Stewart Avenue, Salisbury, S.A. 5018.
1944 HARRIS, J. R., M.Sc., Division of Soils, C.S.I.R.O., Glen Osmond, S.A. 5064.
1963 HARRIS, W. K., B.Sc., Department of Mines, Box 38 Rundle Street P.O., Adelaide S.A. 5000. Programme Secretary, 1965-67; Secretary, 1967-68.
1960 HARRISON, J., 39 Hunter Avenue, St. Ives, N.S.W. 2075.
1963 †HAWKE, V. L., M.B., B.S., 43 Semaphore Road, Semaphore S.A. 5091.
1960 HAYMAN, D. L., Ph.D., Department of Genetics, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1968 HEAD, R. J., Department of Human Physiology and Pharmacology, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1962 *HEATH, G. R., B.Sc. (Hons.), Ph.D., Department of Oceanography, Oregon State University, Corvallis, Oregon, 97331, U.S.A.
1968 HENNINGSEN, M., B.E., F.S.A.S.M., A.M.I.E.A., A.M. Aust. I.M.M., Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000.
1944 HERRIOT, R. I., B.Agr.Sc., Roseworthy Agricultural College, Roseworthy, S.A. 5371.
1968 HIERN, N. M., B.Sc., Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000.
1966 HILLWOOD, E. R., B.Sc., 2 Harris Road, Vale Park, S.A. 5081.
1951 HOCKING, L. J., 40 Kauri Parade, Seacliff, S.A. 5049.
1968 HOPE, R. M., B.Sc. (Hons.), Department of Genetics, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1959 HORWITZ, R. C. H., D.Sc., 19 Kinninmont Avenue, Nedlands, W.A. 6009.
1968 HUTCHISON, A. R., 218 Shepherds Hill Road, Bellevue Heights, S.A. 5050.
1947 *HUTTON, J. T., B.Sc., A.S.A.S.M., C.S.I.R.O., Division of Soils, Private Bag No. 1, Glen Osmond P.O., S.A. 5064. Council, 1957-61, 1965-69; Vice-President, 1961-62, 1963-64; President, 1962-63.
1968 INGLIS, W. G., D.Sc., Ph.D., South Australian Museum, North Terrace, Adelaide, S.A. 5000. Treasurer, 1969-.
1965 JAMES, C. T., M.B., B.S., 134 Fullarton Road, Rose Park, S.A. 5067.
1968 JENKINS, R. J. F., B.Sc. (Hons.), Geology Department, University of Adelaide, S.A. 5001.
1945 *JESSUP, R. W., M.Sc., 6 North Renno Parade, Belair, S.A. 5052. Council, 1961-65.
1950 JOHNS, R. K., M.Sc., Department of Mines, Box 38 Rundle Street P.O., Adelaide, S.A. 5000.
1966 *JOHNSON, J. E., c/- Geosurveys of Australia Pty. Ltd., 57 Todville Street, Woodville West, S.A. 5011.
1963 JONES, J. B., Ph.D., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A. 5000.
1966 KAPEL, A. J., dr.ing., Delhi Australian Petroleum Ltd., Box 1837 P., G.P.O., Adelaide, S.A. 5001.
1967 KENNEDY, C. R., B.Sc., Ph.D., School of Biological Sciences, Flinders University, Bedford Park, S.A. 5042.
1962 KENNY, Mrs. M., South Australian Museum, North Terrace, Adelaide, S.A. 5000.
1939 †KHAKHAR, H. M., Ph.D., M.B., F.R.C.S., Khakhar Building, C.P. Tank Road, Bombay, India.
1935 *KLEEMAN, A. W., Ph.D., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A. 5000. Secretary, 1945-48; Vice-President, 1948-49; 1950-51; President, 1949-50.
1960 KUCHEL, R. H., B.Sc. (Hons.), R.D.Oen., J.P., Botanic Garden, North Terrace Adelaide, S.A. 5000. Council, 1968-.
1965 *LANGE, R. T., B.Sc. (Hons.), Ph.D., Department of Botany, University of Adelaide, North Terrace, Adelaide, S.A. 5000. Councillor, 1969-.

Date of Election

1941 *LANGFORD-SMITH, T., B.A., M.Sc., Ph.D., Department of Geography, University of Sydney, Sydney, N.S.W. 2006.

1965 LEE, D. C., B.Sc., South Australian Museum, North Terrace, Adelaide, S.A. 5000.

1967 *LEE, K. E., D.Sc., C.S.I.R.O., Soils Division, Private Bag No. 1, Glen Osmond, S.A. 5064. Councillor, 1967-.

1922 LENDON, G. A., M.D., B.S., F.R.C.P., c/- Elder's Trustee Executor Co. Ltd., 37 Currie Street, Adelaide, S.A. 5000.

1965 *LINDSAY, J. M., B.Sc., Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000. Programme Secretary 1969-.

1948 LOTHIAN, T. R. N., O.B.E., N.D.H. (N.Z.), Botanic Garden, North Terrace, Adelaide, S.A. 5000. Treasurer, 1952-53; Council 1953-57; Vice-President, 1957-58; 1960-61; President, 1958-60.

1969 LOVE, J. H., B.A., B.D., A.L.A.A., 71 Rowland Road, Hilton, S.A. 5033.

1931 *LUDBROOK, Mrs. N. H., M.A., Ph.D., D.I.C., F.G.S., 110 Watson Avenue, Toorak Gardens, S.A. 5065. Council, 1958-60, 1964-66; Vice-President, 1960-61, 1962-63; President, 1961-62; Librarian, 1966-; Verco Medal, 1963.

1965 MACDONOCHIE, J. R., B.Sc. (Hons.), Primary Industries Branch, Alice Springs, N.T. 5750.

1953 MAELZER, D. A., Ph.D., Waite Institute, Private Bag No. 1, Glen Osmond, S.A. 5064.

1966 MAJOR, R. B., B.Sc. (Hons.), Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000.

1939 MARSHALL, T. J., M.Agr.Sc., Ph.D., C.S.I.R.O., Division of Soils, Private Bag No. 1 Glen Osmond, S.A. 5064.

1966 MARTIN, C. A., M.Sc., Delhi Australian Petroleum Ltd., Box 1837P., G.P.O., Adelaide, S.A. 5001.

1959 *MARTIN, Miss H. A., M.Sc., School of Biological Sciences, University of New South Wales, Box 1, P.O., Kensington, N.S.W. 2033.

1966 MASON, M. G., B.Sc. (Hons.), Department of Mines, Box 38, Rundle Street P.O., Adelaide, S.A. 5000.

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1951 *MITCHELL, F. J., South Australian Museum, North Terrace, Adelaide, S.A. 5000. Treasurer, 1959-67; Vice-President, 1967-68, 1969; President, 1968-69.

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Date of Election

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1934 SHINKFIELD, R. C., 57 Canterbury Avenue, Trinity Gardens, S.A. 5068.

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1941 *SOUTHCOTT, R. V., M.D., B.S., D.Sc., D.T.M. & H., 2 Taylors Rd., Mitcham, S.A. 5062. Verco Medal, 1965; Council, 1949-51, 1952-53, 1957-60, 1965-67; Treasurer, 1951-52; Vice-President, 1953-54, 1955-56, 1961-62; President, 1954-55, 1960-61.

1947 *SPECHT, Prof. R. L., Ph.D., Department of Botany, University of Queensland, St. Lucia, Queensland 4067. Verco Medal, 1961; Council, 1951-52, 1958-60; Programme Secretary, 1952-53; Vice-President, 1961.

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LIST OF LECTURES AND EXHIBITS 1968-69 AND AWARD OF THE SIR JOSEPH VERCO MEDAL

Summary

LIST OF LECTURES GIVEN AT MEETINGS DURING THE YEAR 1968-69

Sept., 1968 Dr. R. J. Swaby: "Resistance of humus to microbial decomposition."
Oct., 1968 Mr. R. Edwards: "The preservation and conservation of aboriginal relics in South Australia."
Nov., 1968 Prof. L. D. Pryor: "Actual and potential ecological amplitude in Eucalyptus."
Apr., 1969 Mr. H. Brideson: "The State Library Australiana Facsimiles."
May, 1969 Dr. K. R. Miles: "Of boots and boats, and geology and arbitrating things" (Presidential Address).
June, 1969 Prof. R. M. Norris: "Aspects of Pleistocene geology."
July, 1969 Prof. R. Peel: "Landscape types and problems in the Sahara."

Exhibits

Mr. J. T. Hutton: "Some results from the use of a Cambridge Geoscan X-ray analyser."
Mr. B. P. Thomson: "Recent maps issued by the Geological Survey of South Australia."
Mr. M. R. Walter: "The interpretation of stromatolites."
Mr. D. E. Symon: "A Pearson Island rat and its young."
Mr. K. Doull: "The nutrition of honey-bees."
Mr. N. McFarland: "Moth eggs."

AWARD OF THE SIR JOSEPH VERCO MEDAL

1929 Prof. Walter Howchin, F.G.S.
1930 John McC. Black, A.L.S.
1931 Prof. Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
1933 Prof. J. Burton Cleland, M.D.
1935 Prof. T. Harvey Johnston, M.A., D.Sc.
1938 Prof. J. A. Prescott, D.Sc., F.A.C.I.
1943 Herbert Womersley, A.L.S., F.R.E.S.
1944 Prof. J. G. Wood, D.Sc., Ph.D.
1945 Cecil T. Madigan, M.A., B.E., D.Sc., F.G.S.
1946 Herbert M. Hale, O.B.E.
1955 L. Keith Ward, I.S.O., B.A., B.E., D.Sc.
1956 N. B. Tindale, B.Sc.
1957 C. S. Piper, D.Sc.
1959 C. G. Stephens, D.Sc.
1960 H. H. Finlayson
1961 R. L. Specht, Ph.D.
1962 H. G. Andrewartha, M.Agr.Sc., D.Sc., F.A.A.
1963 N. H. Ludbrook, M.A., Ph.D., D.I.C., F.G.S.
1965 R. V. Southcott, D.Sc., M.D., B.S., D.T.M. & H.
1966 Prof. A. R. Alderman, D.Sc., Ph.D., F.G.S.
1967 L. D. Pryor, M.Sc., Dip.For.
1968 R. C. Sprigg, M.Sc.
1969 H. B. S. Womersley, D.Sc.

For comprehensive botanical work on marine algae, particularly from southern Australia; research into the taxonomy, ecology and life history of many previously unknown algal species; critical surveys of Chlorophyta (green algae) and Phaeophyta (brown algae) and an important monograph on the *Cystophora* complex (brown algae); papers on various Rhodophyta (red algae), notably Helminthocladiaceae, and several with his students on Ceramiacea. Has collaborated in the Royal Society of London Expedition to the British Solomon Islands Protectorate in 1965; a world authority on the marine algae of the Australasian region; has lectured by invitation at various United States Universities and has built up a recognised research school in the University of Adelaide with library and herbarium, which attracts overseas research students; assisted in the 1947 revision of the handbook, "The Seaweeds of South Australia", Pt. II, by A. H. Lucas and F. Perrin, Adelaide; has published 32 phycological papers, 13 being in collaboration; lecturer and later Reader in the University of Adelaide since 1946.

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